TOTAL MAXIMUM DAILY LOAD (TMDL)

For

pH

In

Crab Orchard Creek

Located In The

Emory River Watershed (HUC 06010208)

Cumberland & Morgan County, Tennessee

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LIST OF ABBREVIATIONS

AMD	Acid Mine Drainage
CFR	Code of Federal regulations
CFS	Cubic Feet per Second
DWPC	Division of Water Pollution Control
EPA	Environmental Protection Agency
HUC	Hydrologic Unit Code
LA	Load Allocation
MGD	Million Gallons per Day
MOS	Margin of Safety
MRLC	Multi-Resolution Land Characteristic
NPDES	National Pollutant Discharge Elimination System
Rf3	Reach File 3
RM	River Mile
TDEC	Tennessee Department of Environment & Conservation
TMDL	Total Maximum Daily Load
USGS	United States Geological Survey
WLA	Waste Load Allocation

SUMMARY SHEET
Proposed Total Maximum Daily Load (TMDL)
Crab Orchard Creek Subwatershed

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1) 303(d) Listed Waterbody Information

State: Tennessee
County: Cumberland & Morgan

Major River Basin: Clinch River Basin
Watershed: Emory River (HUC 06010208)

Waterbody Name: Crab Orchard Creek
Waterbody ID: TN06010208020
Location: From mouth on Emory River to origin
Impacted Stream Length: 28.9 miles Not Supporting
Watershed Area: 47.33 mi^2 (Crab Orchard Creek subwatershed)
Tributary to: Emory River

Constituent(s) of Concern: pH

Designated Uses: Fish and Aquatic Life, Recreation, Livestock Watering & Wildlife, and Irrigation

Applicable Water Quality Standard: Most stringent water quality standard is a range of 6.5 to 9.0 for the Fish & Aquatic Life use classification

2. TMDL Development

Analysis Methodology: Based on 2000 Assessment
Load Duration Curve methodology
Net Alkalinity used as surrogate for pH

Critical Conditions: Methodology addresses all flow conditions

Seasonal Variation: Methodology addresses all seasons

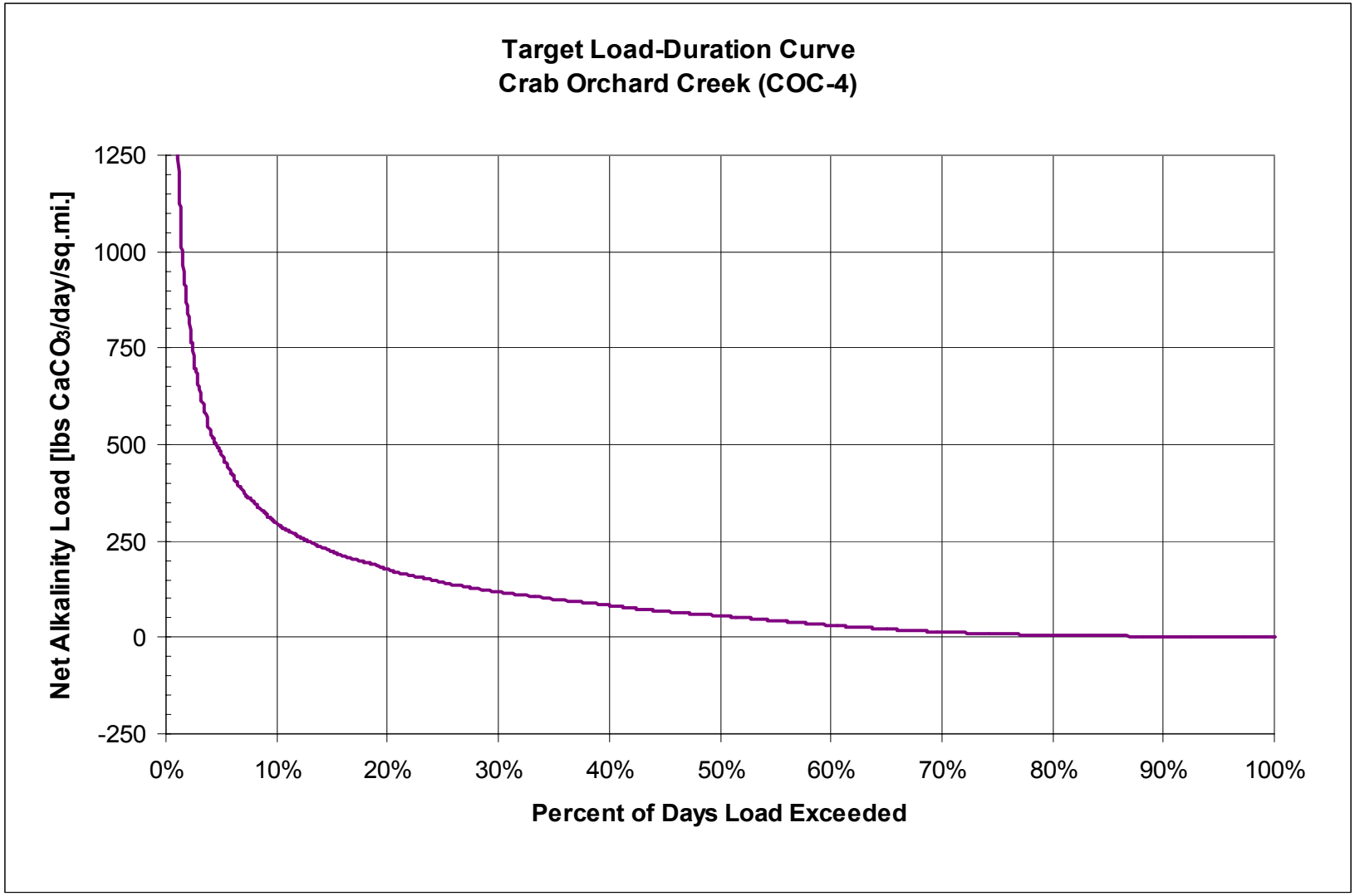
3. TMDL/Allocation

Margin of Safety (MOS): Implicit (conservative modeling assumptions)

Load Allocation: Consists of two components:

1) The pH of waters originating from nonpoint sources shall be 6.5 to 9.0 standard units.

2) Equal to Net Alkalinity load duration curve for the most upstream, fully supporting segment (Crab Orchard Creek upstream of Golliher Creek - see Figure on next page)


Target Load-Duration Curve
Crab Orchard Creek (COC-4)
Net Alkalinity Load [lbs CaCO3/day/sq.mi.]
1250
1000
750
500
250
0
-250
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percent of Days Load Exceeded

PROPOSED
pH TOTAL MAXIMUM DAILY LOAD (TMDL)
EMORY RIVER WATERSHED (HUC 06010208)

Crab Orchard Creek – Mouth on Emory River to Headwaters (TN060010208020)

1.0 INTRODUCTION

Section 303(d) of the Clean Water Act requires each state to list those waters within its boundaries for which technology based effluent limitations are not stringent enough to protect any water quality standard applicable to such waters. Listed waters are prioritized with respect to designated use classifications and the severity of pollution. In accordance with this prioritization, states are required to develop Total Maximum Daily Loads (TMDLs) for those water bodies that are not meeting designated uses. The TMDL process establishes the allowable loadings of pollutants or other quantifiable parameters for a waterbody based on the relationship between pollution sources and in-stream water quality conditions, so that states can establish water quality based controls to reduce pollution from both point and non-point sources and restore and maintain the quality of their water resources (USEPA, 1991).

2.0 WATERSHED DESCRIPTION

The Emory River watershed (HUC 06010208) is located in eastern Tennessee (Figure 1) and falls within the Level III Southwestern Appalachians (68) and Central Appalachians (69) ecoregions. A small northeastern portion of the watershed is in the Level IV Cumberland Mountains subecoregion (69d). The remainder of the watershed, including Crab Orchard Creek, is located in the Level IV Cumberland Plateau subecoregion (68a). Elevations in the Cumberland Plateau are generally 1200–2000 feet, with the Crab Orchard Mountains reaching over 3000 feet. Pennsylvania-age conglomerate, sandstone, siltstone, and shale is covered by mostly well-drained, acid soils of low fertility. The region is mostly forested with areas of agriculture, pine plantations, and coal mining activities (USEPA, 1997).

The Emory River watershed has approximately 1,560 miles of streams (Rf3) and drains a total area of 870 square miles. Watershed land use distribution is based on the Multi-Resolution Land Characteristic (MRLC) databases derived from Landsat Thematic Mapper digital images from the period 1990-1993. Land use for the Emory River watershed is summarized in Table 1. Land use for the Crab Orchard Creek subwatershed is also summarized in Table 1 and shown in Figure 2.

3.0 PROBLEM DEFINITION

EPA Region IV approved Tennessee's final 1998 303(d) list (TDEC, 1998) on September 17, 1998. The list identified 28.9 miles of Crab Orchard Creek (from the mouth on the Emory River to the headwaters) as not supporting designated use classifications due, in part, to pH associated with abandoned mines. The designated use classifications for Crab Orchard Creek and its tributaries include fish and aquatic life, irrigation, livestock watering & wildlife, and recreation.

Figure 1 Location of Emory River Watershed

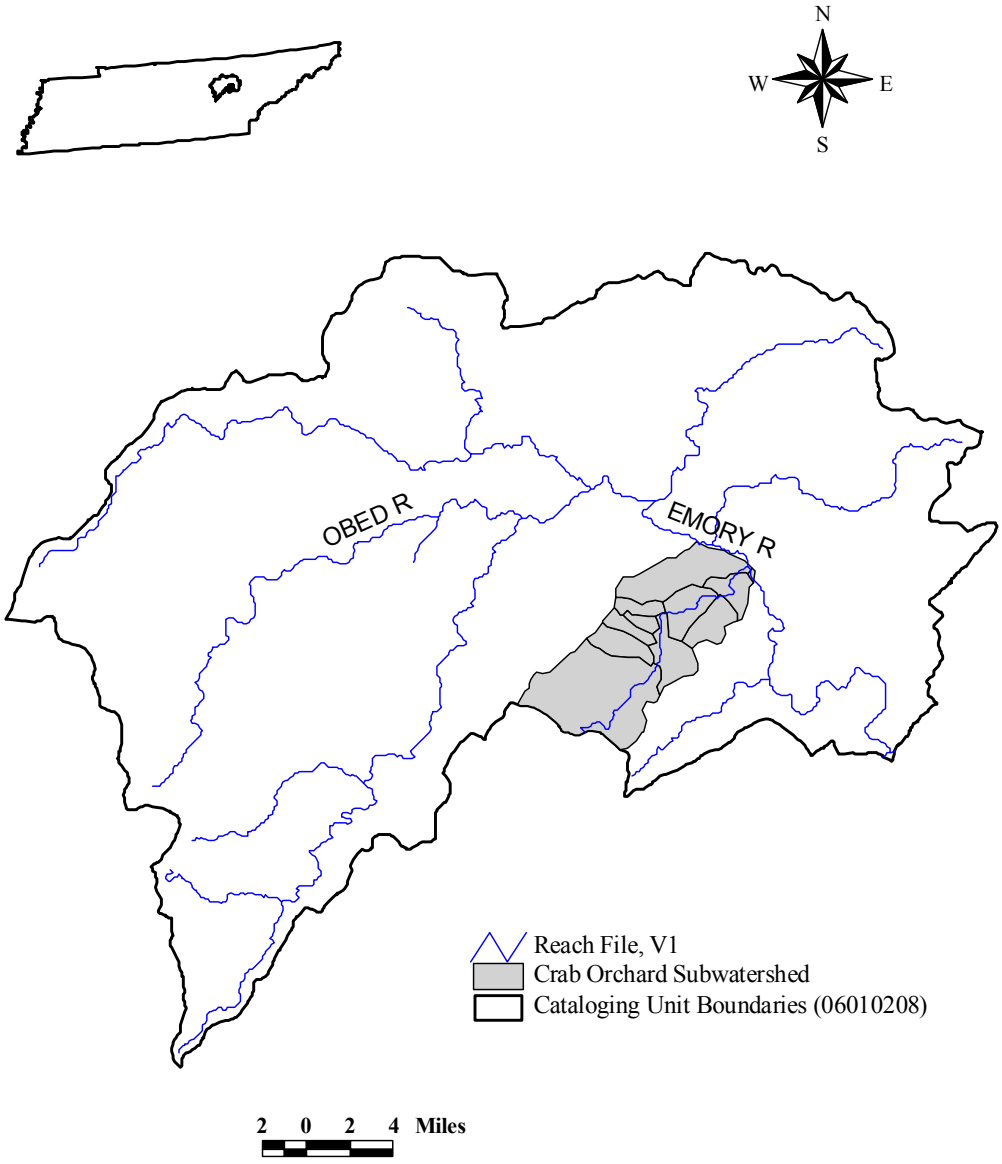
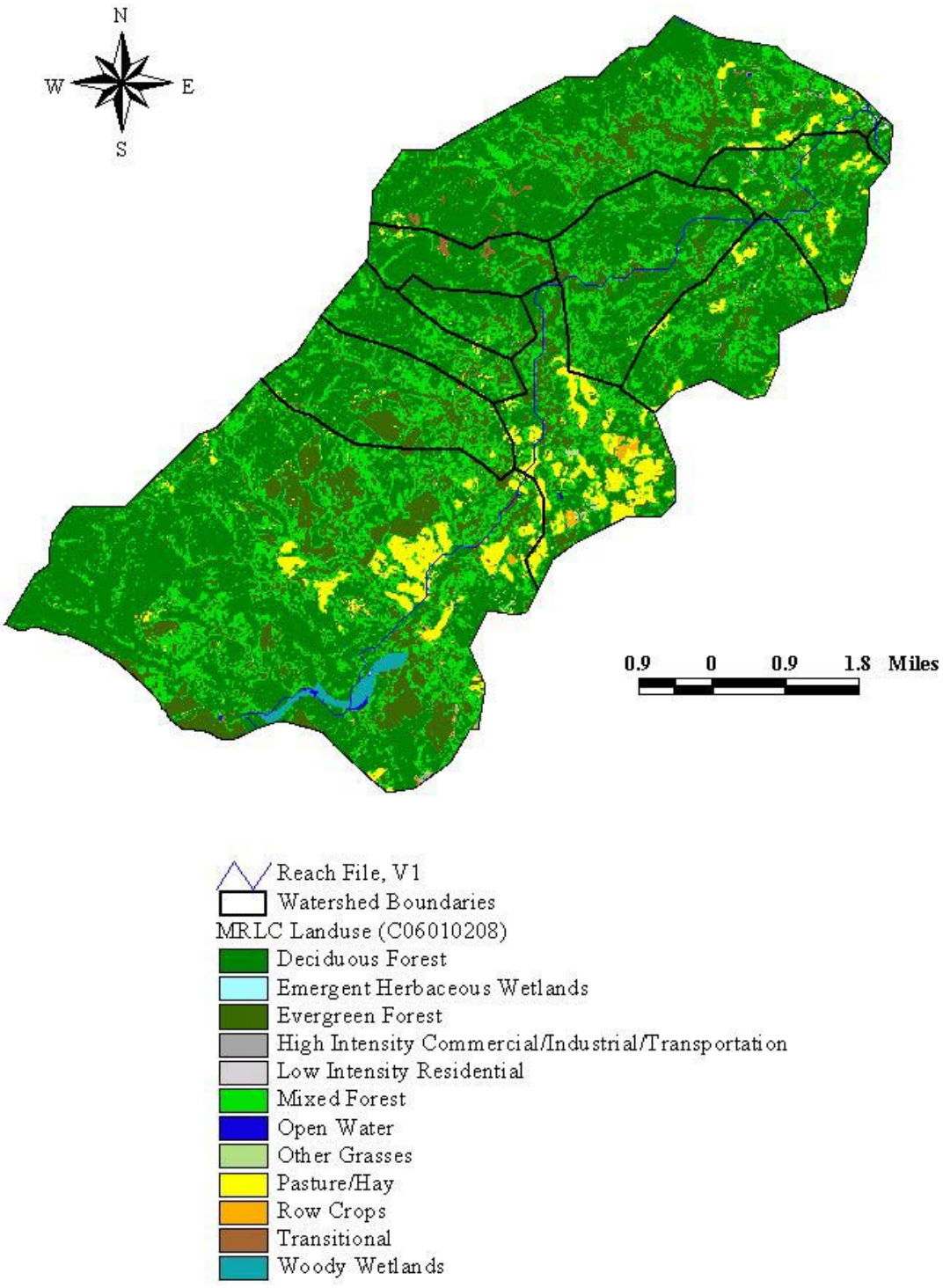


Table 1 Land Use Distribution – Emory River Watershed & Crab Orchard Creek Subwatershed

Land use	Crab Orchard Creek Subwatershed (06010208020)		Total Emory River Watershed (06010208)	
	[acres]	[%]	[acres]	[%]
Bare Rock/Sand/Clay	0	0	1	0
Deciduous Forest	16,577	54.7	295,339	53.0
Emergent Herbaceous Wetlands	0	0	23	0
Evergreen Forest	4,352	14.4	68,077	12.2
High Intensity Commercial/Industrial/Transportation	40	0.1	2,487	0.4
High Intensity Residential	0	0	335	0.1
Low Intensity Residential	27	0.1	4,158	0.7
Mixed Forest	7,285	24.0	119,778	21.5
Open Water	22	0.1	3,781	0.7
Other Grasses (Urban/recreational; e.g. parks law	18	0.1	3,654	0.7
Pasture/Hay	1,642	5.4	48,487	8.7
Row Crops	86	0.3	6,847	1.2
Quarries/Strip Mines/Gravel Pits	0	0	401	0.1
Transitional	90	0.3	1,834	0.3
Woody Wetlands	165	0.5	1,581	0.3
Total	30,304	100.0	556,783	100.0

Figure 2 Crab Orchard Subwatershed Land Use Distribution



Although Tennessee did not issue an updated 303(d) list in 2000, Crab Orchard Creek and its tributaries were reassessed. The results of the 2000 assessment are summarized in Table 2.

Table 2 2000 Assessment – Crab Orchard Creek Subwatershed

Stream Segment	Seg. I.D.	Length [mi.]	Use Support	Cause	Source
Smith Branch	0100	5.4	PS	pH	RE/AM
Lick Branch	0200	2.5	NA		
Henson Creek	0300	5.4	NA		
Golliher Creek	0400	5.6	NS	pH, Metals, Mn, Fe	RE/AM
Fagan Mill Ck.	0500	2.6	NS	pH, Metals, Mn	RE/AM
Laurel Creek	0600	2.7	PS	pH	RE/AM
Mill Creek	0700	12.5	FS		
Misc. Tribs. to COC	0999	25.4	NA		
Crab Orchard Ck.	1000	0.4	FS		
Crab Orchard Ck.	2000	2.3	PS	pH	RE/AM
Crab Orchard Ck.	3000	7.9	NS	pH, Metals, Mn	RE/AM
Crab Orchard Ck.	4000	10.7	FS		

Note: RE/AM = Resource Extraction, Abandoned Mining; FS = Fully Supporting
NS = Not Supporting; PS = Partially Supporting; NA = Not Assessed

Since the 2000 assessment is based on the latest field data (1999-2000), and is more specific as to stream segments impaired, the TMDL analysis will be based on it. The primary cause of impairment is considered to be pH caused by acid mine drainage (AMD). Information regarding AMD formation is contained in Appendix A.

4.0 TARGET IDENTIFICATION

The allowable instream range of pH for the Crab Orchard Creek subwatershed, is established in *State of Tennessee Water Quality Standards, Chapter 1200-4-3 General Water Quality Criteria, October, 1999* (TDEC, 1999) for applicable use classifications. The Fish & Aquatic Life criteria pH range of 6.5 to 9.0 is the most stringent.

According to the Pennsylvania Department of Environmental Protection, the “acidity or net alkalinity of a solution, not the pH, is probably the best single indicator of the severity of AMD.” In order to facilitate analysis of existing pollutant loads and load reductions required to restore the Crab Orchard Creek subwatershed to fully supporting all of its designated use classifications, net alkalinity will be used as a surrogate parameter for TMDL development. For the purposes of this TMDL, the following terms are defined:

Acidity	The quantitative capacity of a water to react with a strong base to a designated pH. Expressed as milligrams per liter calcium carbonate.
Total Alkalinity	A measure of the ability of water to neutralize acids. Expressed as milligrams per liter calcium carbonate.
Net Alkalinity	The total alkalinity minus the acidity. Expressed as milligrams per liter calcium carbonate.

Water quality monitoring of the Crab Orchard Creek subwatershed was conducted by Division of Water Pollution Control (DWPC) personnel from the Knoxville Environmental Assistance Center (EAC) during the period from 10/5/99 through 6/20/00 (See Appendix B & Table 3). Monitoring stations were located at several points in Crab Orchard Creek and near the mouth of major tributaries (see Figure 3). Since there is no specified numerical criteria for net alkalinity, the average net alkalinity (11.2 mg/l $CaCO_3$) of the most upstream, unimpaired section of the Crab Orchard Creek subwatershed (segment 06010208020_4000, upstream of Golliher Creek) was selected as the numerical target for this TMDL.

The linkage between pH and net alkalinity and the appropriateness of the net alkalinity numerical target can be demonstrated through inspection of monitoring data presented in Table 4. Negative net alkalinity values correspond to instream pH less than 6.5, while, with one exception, all samples with net alkalinity concentrations greater than 11.2 mg/l have pH that is in compliance with water quality standards. In addition, the results of a recent biorecon of the upstream reference segment of Crab Orchard Creek are consistent with its fully supporting status (see Appendix C).

In order to characterize net alkalinity (as $CaCO_3$) over the range of flow conditions encountered in the subwatershed, the target net alkalinity (as $CaCO_3$) is expressed by means of a target load duration curve. The target load duration curve, developed in Appendix D and shown in Figure 4, was derived on a unit area basis and is applicable to all stream segments in the subwatershed. In order to meet Tennessee Water Quality Standards for pH, this TMDL requires that net alkalinity (as $CaCO_3$) loads of streams in the Crab Orchard Creek subwatershed meet , or exceed, the loads per unit area specified in the target load duration curve (Figure 4).

5.0 WATER QUALITY ASSESSMENT AND DIFFERENCE FROM TARGET

The flow, acidity, and total alkalinity data collected at each monitoring site (ref: Appendix B) in the Crab Orchard Creek subwatershed are tabulated in Table 3. For each site, net alkalinity was calculated and compared to the target load duration curve using the methodology described in Appendix E. In each case, calculated net alkalinity loads deviated from the target load duration curve as shown in Figures E-1 through E-10. As a point of reference, the instream pH corresponding to net alkalinity concentrations for subwatershed monitoring sites are summarized in Table 4.

It should be noted that for a number of samples, the total alkalinity or acidity were reported as “not detected”. The detection limits for these samples were 1 mg/l for total alkalinity and 10 mg/l for acidity. For purposes of calculating net alkalinity, the analyte concentrations were estimated to

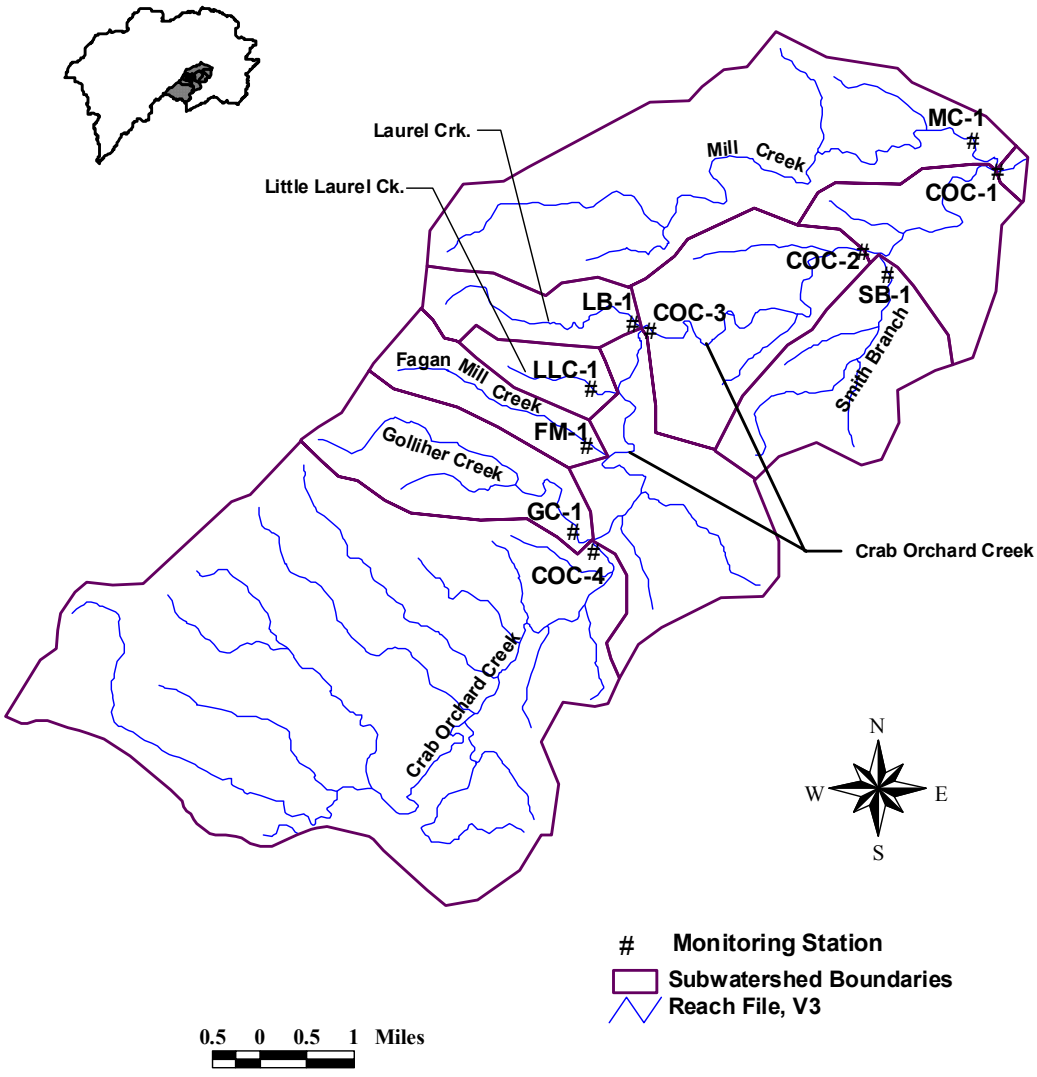


Figure 3 Crab Orchard Creek Subwatershed Monitoring Stations

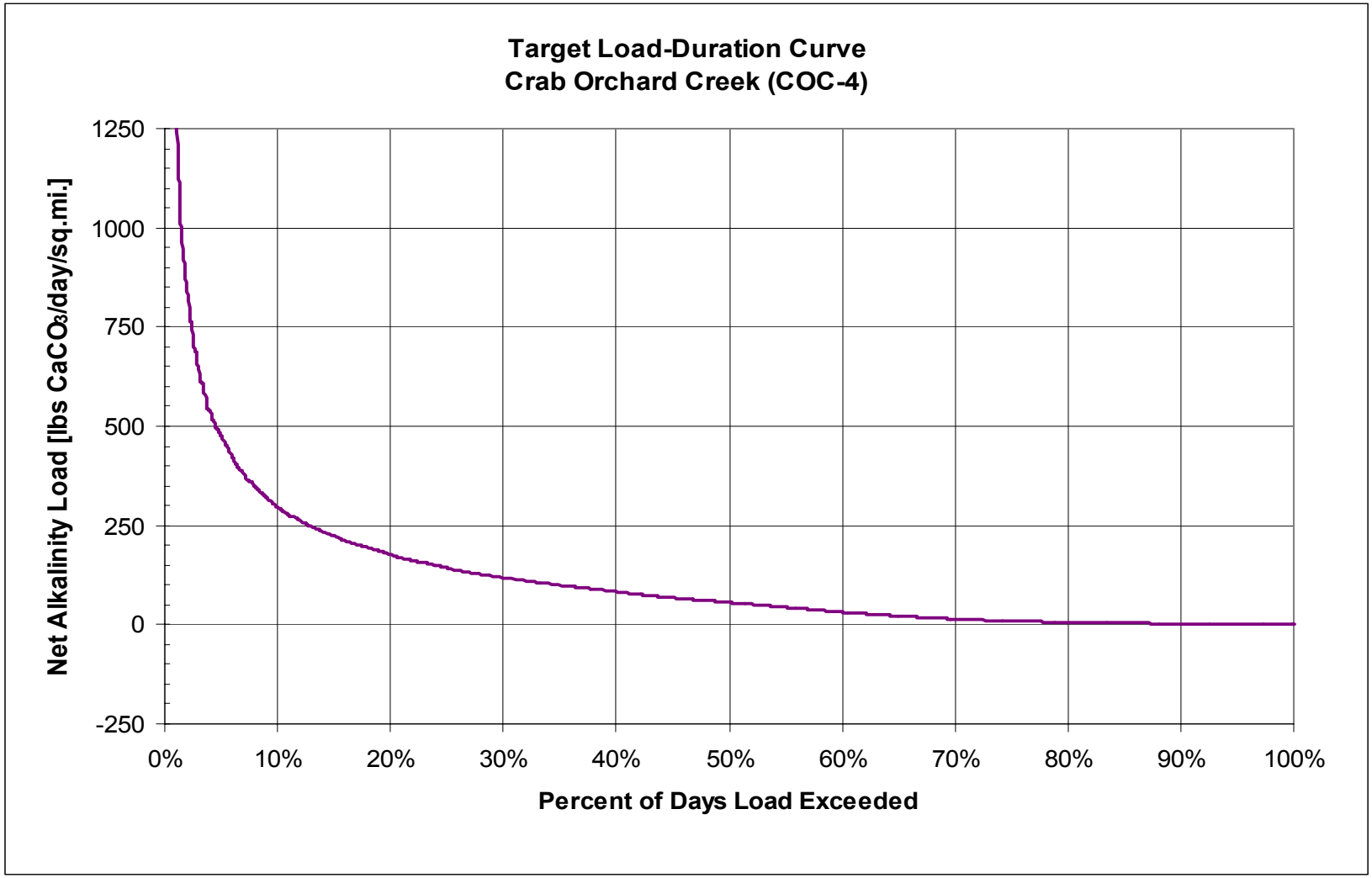


Figure 4 Target Net Alkalinity Load Duration Curve

Table 3 Crab Orchard Creek Subwatershed Monitoring Data (10/5/99 – 6/20/00)

Monitoring Site	Parameter	Units	Sample Date													
			10/5/99	*10/13/99*	*10/26/99*	*11/8/99*	*11/15/99*	*12/1/99*	*12/15/99*	*1/12/00*	*2/16/00*	*3/9/00*	*4/18/00*	*5/10/00*	*5/16/00*	*6/20/00*
Crab Orchard Ck.	Flow	cfs	0.11	0.71	0.32	1.19	0.62	0.92	18.98	26.45	83.86	22.77	41.41	6.54	1.65	1.59
COC-4	Total Alkalinity	mg/l[a]	29	30	26	25	25	20	8	7	5	6	5	9	12	20
	Acidity	mg/l[a]	U[b]	U[b]	U[b]	U[b]	U[b]	U[b]	U[b]	U[b]	U[b]	U[b]	U[b]	U[b]	U[b]	U[b]
Golliher Creek	Flow	cfs	0.072	0.23	0.16	0.282	0.12	0.092	3.34	4.31	14.66	3.6	3.8	1.24	0.18	0.27
GC-1	Total Alkalinity	mg/l[a]	U[b]	U[b]	U[b]	U[b]	U[b]	U[b]	U[b]	U[b]	U[b]	U[b]	U[b]	U[b]	U[b]	U[b]
	Acidity	mg/l[a]	102	96	113	99	97	68	20	15	16	18	19	34	52	51
Fagan Mill Creek	Flow	cfs	0.001	0.01	0.02	0.063	0.33	0.043	1.97	2.59	7.73	1.64	3.61	0.61	0.22	0.12
FM-1	Total Alkalinity	mg/l[a]	U[b]	U[b]	U[b]	U[b]	U[b]	U[b]	3	3	2	2	U[b]	U[b]	U[b]	U[b]
	Acidity	mg/l[a]	152	86	125	54	67	24	U[b]	U[b]	12	U[b]	15	23	45	50
Little Laurel Creek	Flow	cfs	--	--	--	--	--	0.016	0.59	0.81	4.15	1.46	2.02	0.24	0.09	0.03
LLC-1	Total Alkalinity	mg/l[a]	--	--	--	--	--	3	2	3	2	2	2	3	2	5
	Acidity	mg/l[a]	--	--	--	--	--	14	12	U[b]	U[b]	U[b]	U[b]	U[b]	17	16
Laurel Creek	Flow	cfs	--	0.004	0.01	0.06	0.3	0.066	1.48	2.17	--	1.68	3.45	0.25	0.03	0.07
LB-1	Total Alkalinity	mg/l[a]	--	--	3	3	3	3	2	2	--	2	2	2	2	U[b]
	Acidity	mg/l[a]	--	--	U[b]	U[b]	U[b]	U[b]	U[b]	U[b]	--	U[b]	U[b]	U[b]	U[b]	U[b]
Crab Orchard Ck.	Flow	cfs	--	2.36	0.26	1.38	0.51	1.13	31.99	50.71	--	38.5	64.76	8.55	5.81	2.77
COC-3	Total Alkalinity	mg/l[a]	--	4	U[b]	4	2	4	5	5	--	2	2	2	2	2
	Acidity	mg/l[a]	--	U[b]	32	U[b]	11	U[b]	U[b]	U[b]	--	U[b]	U[b]	U[b]	U[b]	U[b]
Crab Orchard Ck.	Flow	cfs	0.56	2.33	0.6	2.16	1.23	1.48	34.12	49.61	146.83	40.39	69.29	11.12	4.56	4.62
COC-2	Total Alkalinity	mg/l[a]	6	2	5	3	3	2	5	4	3	3	2	2	3	3
	Acidity	mg/l[a]	U[b]	10	U[b]	U[b]	U[b]	U[b]	U[b]	U[b]	U[b]	U[b]	U[b]	U[b]	U[b]	U[b]
Smith Branch	Flow	cfs	0.09	0.22	0.15	0.23	0.12	0.13	2.13	4.11	13.51	2.66	4.34	0.98	0.53	0.32
SB-1	Total Alkalinity	mg/l[a]	11	8	11	9	11	7	7	4	2	4	3	5	6	7
	Acidity	mg/l[a]	12	10	12	16	12	U	U	U	U	U	U	U	U	U
Mill Creek	Flow	cfs	0.27	0.59	0.24	0.61	0.03	0.28	7.91	11.57	37.87	9.25	13.28	2.08	1.07	0.7
MC-1	Total Alkalinity	mg/l[a]	24	17	22	16	19	11	5	4	2	3	3	6	8	12
	Acidity	mg/l[a]	U[b]	U[b]	U[b]	U[b]	U[b]	U[b]	U[b]	U[b]	U[b]	U[b]	U[b]	U[b]	U[b]	U[b]
Crab Orchard Ck.	Flow	cfs	0.76	3.81	0.78	3.01	1.61	1.46	40.46	60.45	207.43	49.44	99.75	15.63	8.14	6.17
COC-1	Total Alkalinity	mg/l[a]	12	4	6	5	7	5	5	6	3	3	3	4	5	5
	Acidity	mg/l[a]	U[b]	U[b]	U[b]	U[b]	U[b]	U[b]	U[b]	U[b]	U[b]	U[b]	U[b]	U[b]	U[b]	U[b]

a mg/l $CaCO_3$

b U denotes analyte requested but not detected. Detection limit is 1 mg/l for total alkalinity and 10 mg/l for acidity.

Table 4 Comparison of Crab Orchard Creek Subwatershed pH & Net Alkalinity

Monitoring Site	Parameter	Units	Sample Date													
			10/5/99	*10/13/99*	*10/26/99*	*11/8/99*	*11/15/99*	*12/1/99*	*12/15/99*	*1/12/00*	*2/16/00*	*3/9/00*	*4/18/00*	*5/10/00*	*5/16/00*	*6/20/00*
Crab Orchard Ck.	pH	--	6.8	6.5	7.7	6.8	6.6	7.0	5.9	6.0	6.3	7.8	7.6	7.2	7.3	7.2
COC-4	Net Alkalinity	mg/l[a]	24	25	21	20	20	15	3	2	0	1	0	4	7	15
Golliher Creek	pH	--	3.6	3.2	3.1	3.3	2.9	3.2	3.0	3.0	4.3	4.0	4.0	3.6	3.5	3.3
GC-1	Net Alkalinity	mg/l[a]	-101.5	-95.5	-112.5	-98.5	-96.5	-67.5	-19.5	-14.5	-15.5	-17.5	-18.5	-33.5	-51.5	-50.5
Fagan Mill Creek	pH	--	3.6	3.3	3.2	3.6	3.1	3.6	4.6	4.4	4.8	4.5	4.6	3.9	3.5	3.4
FM-1	Net Alkalinity	mg/l[a]	-151.5	-85.5	-124.5	-53.5	-66.5	-23.5	-2	-2	-10	-3	-14.5	-22.5	-44.5	-49.5
Little Laurel Creek	pH	--	--	--	--	--	--	5.5	4.8	3.7	5.3	5.2	5.6	5.2	5.3	5.3
LLC-1	Net Alkalinity	mg/l[a]	--	--	--	--	--	-11	-10	-2	-3	-3	-3	-2	-15	-11
Laurel Creek	pH	--	--	--	4.8	5.6	4.5	5.7	4.9	4.5	--	5.3	5.3	5.3	5.2	5.2
LB-1	Net Alkalinity	mg/l[a]	--	--	-2	-2	-2	-2	-3	-3	--	-3	-3	-3	-3	-4.5
Crab Orchard Ck.	pH	--	--	5.2	4.0	5.9	4.6	6.3	6.5	5.2	--	5.8	5.7	5.3	4.9	4.8
COC-3	Net Alkalinity	mg/l[a]	--	-1	-31.5	-1	-9	-1	0	0	--	-3	-3	-3	-3	-3
Crab Orchard Ck.	pH	--	6.2	5.0	5.9	5.3	5.6	5.7	6.5	5.3	6.1	5.9	6.0	5.8	5.9	5.7
COC-2	Net Alkalinity	mg/l[a]	1	-8	0	-2	-2	-3	0	-1	-2	-2	-3	-3	-2	-2
Smith Branch	pH	--	5.8	5.7	5.6	6.2	5.9	6.3	6.4	4.8	5.6	5.7	5.8	5.8	5.9	5.8
SB-1	Net Alkalinity	mg/l[a]	-1	-2	-1	-7	-1	2	2	-1	-3	-1	-2	0	1	2
Mill Creek	pH	--	6.7	6.6	6.1	7.0	7.1	7.1	6.0	5.7	6.0	6.3	6.4	6.4	6.5	6.6
MC-1	Net Alkalinity	mg/l[a]	19	12	17	11	14	6	0	-1	-3	-2	-2	1	3	7
Crab Orchard Ck.	pH	--	6.8	6.1	6.4	6.4	6.8	6.5	6.0	5.9	6.3	6.3	6.4	6.5	6.6	6.6
COC-1	Net Alkalinity	mg/l[a]	7	-1	1	0	2	0	0	1	-2	-2	-2	-1	0	0

a mg/l $CaCO_3$

be one half of the appropriate detection limit. The net alkalinity values for Crab Orchard Creek (COC-4), Golliher Creek, and Fagan Mill Creek clearly reflect the use support status in the 2000 Assessment (ref.: Table 2). The net alkalinity results for the remaining waterbodies, however, are not as straightforward. In many instances, undetected acidity and low, positive total alkalinity concentrations yield ambiguous results (i.e. calculated net alkalinity is lower than ½ of the acidity detection limit). Although, using the assumption of one half of the detection level, the calculated net alkalinity is mathematically negative, the actual net alkalinity can range from negative 10 mg/l $CaCO_3$ to slightly positive.

6.0 SOURCE ASSESSMENT

An important part of the TMDL analysis is the identification of individual sources, or source categories, of low pH in the subwatershed and the amount of pollutant loading contributed by each of these sources. Sources are broadly classified as either point or non-point sources. A point source can be defined as a discernable, confined, and discrete conveyance from which pollutants are or may be discharged to surface waters. Non-point sources include all other sources of pollution.

6.1 Point Sources

There are no known point source discharges of low pH effluent in the Crab Orchard Creek subwatershed.

6.2 Non-point Sources

There are a number of abandoned surface mining sites in the Crab Orchard Creek subwatershed that are susceptible to the formation of acid mine drainage as discussed in Appendix A. In the 2000 water quality assessment (ref.: Table 2), resource extraction and abandoned mining were identified as the sources of low pH in impaired waterbodies in the subwatershed.

7.0 DEVELOPMENT OF TOTAL MAXIMUM DAILY LOAD

The TMDL process quantifies the amount of a pollutant that can be assimilated in a waterbody, identifies the sources of the pollutant, and recommends regulatory or other actions to be taken to achieve compliance with applicable water quality standards based on the relationship between pollution sources and in-stream water quality conditions. A TMDL can be expressed as the sum of all point source loads (Waste Load Allocations), non-point source loads (Load Allocations), and an appropriate margin of safety (MOS) which takes into account any uncertainty concerning the relationship between effluent limitations and water quality:

$$TMDL = \Sigma WLAs + \Sigma LAs + MOS$$

The objective of a TMDL is to allocate loads among all of the known pollutant sources throughout a watershed so that appropriate control measures can be implemented and water quality standards achieved. 40 CFR §130.2 (i) states that TMDLs can be expressed in terms of mass per time (e.g. pounds per day), toxicity, or other appropriate measure.

7.1 TMDL Representation

In general, waterbodies become impaired due to excessive loading of particular pollutants that result in concentrations that violate instream water quality standards. A TMDL establishes the maximum load that can be assimilated by the waterbody, without violating standards, and allocates portions of this load to point and non-point sources. This normally involves reductions in loading from existing levels, with WLAs & LAs of zero as the ideal.

The use of net alkalinity as a surrogate parameter, however, requires a different approach. Existing levels of net alkalinity in impaired subwatersheds are negative, while target values are positive. The concept of a "maximum net alkalinity load" does not appropriately represent the desired target condition with respect to AMD caused impairment. Net alkalinity targets can be achieved by reducing acidity, increasing total alkalinity, or some combination of both.

The net alkalinity TMDL for the Crab Orchard Creek subwatershed, in part, is considered to correspond to the target load duration curve for the fully supporting segment of Crab Orchard Creek, upstream of the confluence with Golliher Creek, developed in Appendix D.

7.2 Margin of Safety

There are two methods for incorporating an MOS in the analysis: a) implicitly incorporate the MOS using conservative model assumptions to develop allocations; or b) explicitly specify a portion of the TMDL as the MOS and use the remainder for allocations. In this TMDL, an implicit MOS was incorporated through the use of conservative modeling assumptions. These include: 1) the use of the load duration curve, which addresses pollutant loading over the entire range of flow and 2) the use of a positive net alkalinity target based on an upstream, fully supporting section of Crab Orchard Creek.

7.3 Determination of Total Maximum Daily Loads

The TMDL for net alkalinity in the Crab Orchard Creek subwatershed is defined by the target load duration curve (ref: Figures D-3 & 4). Since this curve was derived on a unit drainage area basis, it is applicable to all subwatersheds.

7.4 Determination of WLAs, & LAs

As previously stated, the TMDL can be expressed as the sum of all Waste Load Allocations (WLAs), Load Allocations (LAs), and an appropriate margin of safety (MOS). Considering the conservative analysis (implicit MOS) and that there are no identified point sources of acid mine drainage in the Crab Orchard Creek subwatershed, the TMDL equation reduces to:

$$TMDL = \Sigma LAs$$

where: $\Sigma WLAs = MOS = 0$

The LA for each subwatershed, then, is equal to: 1) the target load duration curve (ref: Figures D-3 & 4) determined on a unit drainage area basis; and 2) the requirement that the pH of waters originating from nonpoint sources shall be 6.5 to 9.0 standard units.

7.5 Seasonal Variation

The target load duration curve, and therefore the TMDL and LAs, is applicable over the entire range of flow for all waterbodies in the Crab Orchard Creek subwatershed in all seasons.

8.0 IMPLEMENTATION PLAN

Monitoring conducted in 1999 and 2000 has identified a number of waterbodies in the Crab Orchard Creek subwatershed as impaired due to low pH. This condition is a result of AMD from land disturbance caused by past coal mining activities. It should be noted that the stream water quality documented during sampling conducted for this TMDL is not typical of the more severe acid mine drainage situations Required LAs will be implemented in several steps to reduce acidity and/or increase total alkalinity so as to result in an increase of instream net alkalinity. In order to meet Tennessee Water Quality Standards for pH, this TMDL requires that net alkalinity (as $CaCO_3$) loads of streams in the Crab Orchard Creek subwatershed meet , or exceed, the loads per unit area specified in the target load duration curve (ref.: Figure 4).

Step 1: Conduct additional water and minespoil testing to identify specific AMD sites and delineate actual areas of acid production at each site. Currently, there are four problem areas in the Crab Orchard Creek subwatershed documented.

Step 2: Once sites have been identified, remediation plans will be developed utilizing primarily passive treatment schemes (versus treatment by chemical addition) to provide a long-term solution to stream impairment. Remediation measures that have proved successful include, but are not limited to:

- Regrading of spoil
- Isolation of acid producing material from water contact
- Anoxic limestone drains
- Constructed wetlands.

The Abandoned Mine Lands Section of the DWPC has expertise in the development of AMD remediation plans and has completed a number of reclamation projects on abandoned mines in the Tennessee coalfield. A number of these projects have included measures designed to remediate acid production caused by land disturbance due to past mining. One reclamation project was completed in the subwatershed in 1988 at a cost of $117,000.

The Mining Section issues NPDES permits for discharges of wastewater from coal and non-coal mines and, where applicable, Mining Law permits to non-coal facilities in Tennessee. This section of the DWPC has worked with a number permitted mine sites, offering considerable technical advice in the remediation of problems similar to those found in the Crab Orchard Creek subwatershed.

Step 3: Conduct follow-on water quality testing of Crab Orchard Creek and its tributaries to verify the effectiveness of remediation measures. Parameters should include flow, pH, acidity, and total alkalinity.

9.0 PUBLIC PARTICIPATION

In accordance with 40 CFR §130.7, announcement of the availability of proposed pH TMDL for Crab Orchard Creek was made to the public, effected dischargers, and other concerned parties and comments solicited. Steps taken in this regard include:

1) Notice of the proposed TMDLs was posted on the Tennessee Department of Environment and Conservation website on August 6, 2001 (see Appendix F). The announcement stated that public comments would be received through September 20, 2001. As of August 31, 2001, the Public Notice announcement was accessed 45 times and the TMDL document downloaded 120 times.

2) Notice of the availability of the proposed TMDLs (similar to the website announcement) was included in one of the NPDES permit Public Notice mailings which are sent to approximately 90 interested persons or groups who have requested this information.

No written comments were received during the Public Notice period.

10.0 FURTHER INFORMATION

Further information concerning Tennessee's TMDL program can be found on the Internet at the Tennessee Department of Environment and Conservation website:

www.state.tn.us/environment/wpc/tmdl.htm

Technical questions regarding this TMDL should be directed to the following members of the Division of Water Pollution Control staff:

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APPENDIX A

Acid Mine Drainage

Acid Mine Drainage Formation

The following information regarding acid mine drainage formation was taken from the U.S. Department of Interior, Office of Surface Mining (OSM) website at www.osmre.gov/amdform.htm. The first section on the Chemistry of Pyrite Weathering is reproduced below. Discussion of subsequent sections can be found on the OSM website.

The formation of acid drainage is a complex geochemical and microbially mediated process. The acid load ultimately generated from a minesite is primarily a function of the following factors:

- Chemistry
- Microbiological Controls
- Depositional environment
- Acid/base balance of the overburden
- Lithology
- Mineralogy
- Minesite hydrologic conditions

Chemistry of Pyrite Weathering

A complex series of chemical weathering reactions are spontaneously initiated when surface mining activities expose spoil materials to an oxidizing environment. The mineral assemblages contained in the spoil are not in equilibrium with the oxidizing environment and almost immediately begin weathering and mineral transformations. The reactions are analogous to "geologic weathering" which takes place over extended periods of time (i.e., hundreds to thousands of years) but the rates of reaction are orders of magnitude greater than in "natural" weathering systems. The accelerated reaction rates can release damaging quantities of acidity, metals, and other soluble components into the environment. The pyrite oxidation process has been extensively studied and has been reviewed by Nordstrom (1979). For purposes of this description, the term "pyrite" is used to collectively refer to all iron disulfide minerals.

The following equations show the generally accepted sequence of pyrite reactions:

$2\ FeS_2 + 7\ 0_2 + 2\ H_2O \rightarrow\rightarrow 2\ Fe^{2+} + 4\ SO_4^{2-} + 4\ H^+$ (Equation 1)

$4\ Fe^{2+} + O_2 + 4\ H^+ \rightarrow 4\ Fe^{3+} + 2\ H_2O$ (Equation 2)

$4\ Fe^{3+} + 12\ H_2O \rightarrow 4\ Fe(OH)_3 + 12\ H^+$ (Equation 3)

$FeS_2 + 14\ Fe^{3+} + 8\ H_2O \rightarrow 15\ Fe^{2+} + 2\ SO_4^{2-} + 16\ H^+$ (Equation 4)

In the initial step, pyrite reacts with oxygen and water to produce ferrous iron, sulfate and acidity. The second step involves the conversion of ferrous iron to ferric iron. This second reaction has been termed the "rate determining" step for the overall sequence.

The third step involves the hydrolysis of ferric iron with water to form the solid ferric hydroxide (ferrihydrite) and the release of additional acidity. This third reaction is pH dependent. Under very

acid conditions of less than about pH 3.5, the solid mineral does not form and ferric iron remains in solution. At higher pH values, a precipitate forms, commonly referred to as “yellowboy.”

The fourth step involves the oxidation of additional pyrite by ferric iron. The ferric iron is generated by the initial oxidation reactions in steps one and two. This cyclic propagation of acid generation by iron takes place very rapidly and continues until the supply of ferric iron or pyrite is exhausted. Oxygen is not required for the fourth reaction to occur.

The overall pyrite reaction series is among the most acid-producing of all weathering processes in nature.

APPENDIX B

Crab Orchard Creek Monitoring Data

Table B-1 Crab Orchard Creek (COC-4) Monitoring Data

Crab Orchard Creek **35 58'10.1"N**
Noah Hamby Road (WMA Road) **84 40'14.4"W**
COC-4

Test	*Units*	*10/5/99*	*10/13/99*	*10/26/99*	*11/8/99*	*11/15/99*	*12/1/99*	*12/15/99*	*1/12/00*	*2/16/00*	*3/9/00*	*4/18/00*	*5/10/00*	*5/16/00*	*6/20/00*
Acidity	mg/l*	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Dissolved Oxygen	mg/l	9.07	7.42	9.04	9.36	5.75	10.95	11.43	11.71	12.06	10.9	10.95	8.36	8.72	6.74
Dissolved Residue	mg/l	40	35	35	35	27	13	10	15	U	18	U	29	18	30
pH		6.83	6.53	7.74	6.8	6.56	6.95	5.85	6.02	6.28	7.84	7.6	7.18	7.25	7.17
Specific Conductivity	uMHO	117	71	86	71	66	65	39	43	24	24	23	31	35	50
Sulfate	mg/l	5	10	12	9	9	11	7	7	6	7	6	7	7	8
Suspended Residue	mg/l	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Temperature	Celsius	14.0	16.3	7.1	9.6	9.2	3.6	6.6	5.0	7.1	10.0	11.8	18.2	14.5	21.43
Total Alkalinity	mg/l*	29	30	26	25	25	20	8	7	5	6	5	9	12	20
Total Dissolved Solids	g/l	0.081	0.046	0.057	0.048	0.043	0.092	0.029	0.021	0.015	0.16	0.015	0.02	0.024	0.03
Total Hardness	mg/l	29	32	29	29	26	25	14	12	11	11	10	15	15	28
Turbidity	NTU	1.3	3.3	2.1	2.2	1.5	1.2	1.3	0.8	1.5	1.3	1.1	1.8	3.9	3.2
Aluminum	ug/l	257	230	122	107	U	219	101	122	210	157	217	142	138	417
Calcium	mg/l	13.3	7.86	8.75	8.57	7.67	6.64	3.56	3.00	2.21	2.66	2.59	3.5	4.22	7.39
Copper	ug/l	1	2	3	U	U	U	U	U	U	U	U	3	U	U
Iron	ug/l	105	460	233	176	154	153	100	71	77	88	41	107	227	295
Lead	ug/l	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Manganese	ug/l	380	348	33	40	52	12	18	U	31	34	44	38	25	85
Nickel	ug/l	20	U	U	U	U	U	U	U	U	U	U	U	U	U
Zinc	ug/l	19	17	9	U	U	6	3	1	2	6	3	4	1	3
Salinity	ppt	0.06	0.03	0.04	0.03	0.03	0.03	0.02	0.01	0.01	0.01	0.01	0	0.01	0
Flow	cfs	0.11	0.71	0.32	1.19	0.62	0.92	18.98	26.45	83.86	22.77	41.41	6.54	1.65	1.59

* mg/l $CaCO_3$

Table B-2 Golliher Creek Monitoring Data

Golliher Creek **35 58'20.6"N**
Noah Hamby Road (WMA Road) **84 40'27.1"W**
GC-1

Test	*Units*		*10/5/99*	*10/13/99*	*10/26/99*	*11/8/99*	*11/15/99*	*12/1/99*	*12/15/99*	*1/12/00*	*2/16/00*	*3/9/00*	*4/18/00*	*5/10/00*	*5/16/00*	*6/20/00*
Acidity	mg/l*		102	96	113	99	97	68	20	15	16	18	19	34	52	51
Dissolved Oxygen	mg/l		8.67	8.82	11.24	10.42	6.7	12.93	12.16	12.11	12.06	11.31	11.41	10.07	11.1	8.78
Dissolved Residue	mg/l		317	272	334	252	270	158	39	28	24	38	35	97	150	153
pH			3.55	3.16	3.09	3.3	2.9	3.24	2.98	2.96	4.29	4	4.02	3.62	3.47	3.33
Specific Conductivity	uMHO		522	499	562	478	516	369	87	74	49	75	77	165	240	274
Sulfate	mg/l		293	217	263	199	281	169	31	22	18	28	26	69	103	109
Suspended Residue	mg/l			U	U	U	U	U	U	U	U	U	U	U	U	U
Temperature	Celsius		13.6	15.8	6.9	10.5	9.6	2.9	6.9	5.3	7.8	9.7	11.1	15.8	11.69	18.56
Total Alkalinity	mg/l*		U	U	U	U	U	U	U	U	U	U	U	U	U	U
Total Dissolved Solids	g/l		0.340	0.325	0.366	0.311	0.335	0.240	0.820	0.047	0.031	0.051	0.049	0.110	0.16	0.18
Total Hardness	mg/l		189	150	179	122	161	94	21	14	13	17	16	39	61	65
Turbidity	NTU		U	U	0.5	0.4	U	U	0.3	0.2	U	U	U	U	U	U
Aluminum	ug/l		11900	9450	12500	9560	10500	6350	1340	886	1248	1660	2180	3900	5650	5390
Calcium	mg/l		27.3	19.9	30.6	18.4	24.3	11.8	2.6	1.86	1.34	2.15	1.93	4.62	8.06	9.16
Copper	ug/l		3	4	4	3	3	3	U	U	U	2	1	2	3	3
Iron	ug/l		566	1190	1000	1760	1230	1430	379	349	275	483	364	569	790	467
Lead	ug/l		U	1	U	U	1	U	U	U	U	U	U	U	U	U
Manganese	ug/l		5400	4460	5460	3960	4440	2580	518	284	239	284	382	1080	1960	1880
Nickel	ug/l		207	202	247	191	212	U	18	25	U	30	25	80	101	114
Zinc	ug/l		317	326	352	301	312	210	75	30	31	48	53	117	186	186
Salinity	ppt		0.25	0.24	0.27	0.23	0.25	0.18	0.06	0.03	0.02	0.03	0.03	0.1	0.11	0.1
Flow	cfs		0.072	0.23	0.16	0.282	0.12	0.092	3.34	4.31	14.66	3.6	3.8	1.24	0.18	0.27

* mg/l $CaCO_3$

Table B-3 Fagan Mill Creek Monitoring Data

Fagan Mill Creek **35 59'08.5"N**
Ruth Ruppe Road **84 40'07.1"W**
FMC-1

Test	*Units*	*10/5/99*	*10/13/99*	*10/26/99*	*11/8/99*	*11/15/99*	*12/1/99*	*12/15/99*	*1/12/00*	*2/16/00*	*3/9/00*	*4/18/00*	*5/10/00*	*5/16/00*	*6/20/00*
Acidity	mg/l*	152	86	125	54	67	24	U	U	12	U	15	23	45	50
Dissolved Oxygen	mg/l	7.50	8.40	10.29	9.93	6.19	12.53	11.98	12.03	11.99	10.95	11.28	9.75	10.84	8.58
Dissolved Residue	mg/l	583	298	471	210	228	58	19	19	26	38	43	95	175	201
pH		3.61	3.29	3.21	3.6	3.12	3.58	4.57	4.44	4.83	4.54	4.55	3.85	3.49	3.35
Specific Conductivity	uMHO	737	501	650	386	427	174	46	40	52	57	63	153	273	280
Sulfate	mg/l	475	223	382	166	202	125	14	11	20	25	27	63	117	144
Suspended Residue	mg/l	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Temperature	Celsius	13.1	15.7	6.3	11.0	9.2	3.2	6.9	5.3	7.9	11.2	11.4	16.3	11.96	18.69
Total Alkalinity	mg/l*	U	U	U	U	U	U	3	3	2	2	U	U	U	U
Total Dissolved Solids	g/l	0.479	0.325	0.423	0.250	0.27	0.113		0.023	0.031	0.037	0.041	0.099	0.18	0.182
Total Hardness	mg/l	304	176	255	142	150	63	21	14	15	20	20	51	88	105
Turbidity	NTU	U	U	0.01	0.2	U	U	0.2	0.4	0.4	0.4	0.2	0.2	U	U
Aluminum	ug/l	20500	8040	16500	5480	6810	1640	205	252	1410	882	1830	2220	4080	3790
Calcium	mg/l	51.6	13.8	44	27.2	31.4	11.2	3.25	2.77	2.84	3.86	3.94	9.06	16.6	19.7
Copper	ug/l	8	5	8	3	4	1	U	U	1	1	2	U	2	3
Iron	ug/l	520	623	346	666	412	388	214	320	331	715	672	1720	2040	1670
Lead	ug/l	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Manganese	ug/l	9200	4640	7500	3410	3780	1210	195	105	204	301	385	1140	2310	2390
Nickel	ug/l	323	182	284	118	143	44	U	17	19	22	23	61	84	126
Zinc	ug/l	462	274	394	185	196	63	12	12	40	33	45	89	156	178
Salinity	ppt	0.36	0.24	0.32	0.19	0.277	0.08		0.02	0.02	0.02	0.03	0.07	0.1	0.13
Flow	cfs	0.001	0.01	0.02	0.063	0.33	0.043	1.97	2.59	7.73	1.64	3.61	0.61	0.22	0.12

* mg/l $CaCO_3$

Table B-4 Little Laurel Creek Monitoring Data

Little Laural Creek **35 59'40.3"N**
Ruth Ruppe Road **84 40'04.0"W**
LLC-1

Test	*Units*	*10/5/99*	*10/13/99*	*10/26/99*	*11/8/99*	*11/15/99*	*12/1/99*	*12/15/99*	*1/12/00*	*2/16/00*	*3/9/00*	*4/18/00*	*5/10/00*	*5/16/00*	*6/20/00*
Acidity	mg/l*						14	12	U	U	U	U	U	17	16
Dissolved Oxygen	mg/l						10.42	11.08	11.31	11.61	10.68	10.76	8.45	7.48	1.28
Dissolved Residue	mg/l						42	45	36	20	35	16	44	92	77
pH							5.51	4.77	3.74	5.29	5.15	5.58	5.22	5.3	5.3
Specific Conductivity	uMHO						107	98	72	39	44	29	57	90	186
Sulfate	mg/l						46	36	25	13	19	12	20	55	41
Suspended Residue	mg/l						U	U	U	U	U	U	U	U	U
Temperature	Celsius						5.9	8.3	6.8	8.5	10.9	11.8	15.6	13.13	17.02
Total Alkalinity	mg/l*						3	2	3	2	2	2	3	2	5
Total Dissolved Solids	g/l						0.069	0.069	0.041	0.028	0.028	0.019	0.037	0.058	0.12
Total Hardness	mg/l						48	36	24	14	19	15	25	56	50
Turbidity	NTU						0.8	0.1	U	0.3	0.9	U	0.7	0.1	0.4
Aluminum	ug/l						561	1040	646	379	414	384	458	707	1490
Calcium	mg/l						7.74	5.11	3.50	2.31	3.1	2.58	4.05	8.73	8.65
Copper	ug/l						U	U	U	U	U	U	U	U	U
Iron	ug/l						843	227	139	107	140	54	274	726	974
Lead	ug/l						U	U	U	U	U	U	U	U	U
Manganese	ug/l						1450	117	568	235	373	221	630	1940	1560
Nickel	ug/l						138	19	29	13	20	U	23	31	28
Zinc	ug/l						29	32	28	14	20	10	21	56	31
Salinity	ppt						0.05	0.05	0.03	0.02	0.02	0.01	0.03	0.04	0.1
Flow	cfs						0.016	0.59	0.81	4.15	1.46	2.02	0.24	0.09	0.03

* mg/l $CaCO_3$

Table B-5 Laurel Creek Monitoring Data

Laurel Branch **36 00'12.4"N**
Catoosa WMA **84 39'25.0"W**
LB-1

Test	*Units*	*10/5/99*	*10/13/99*	*10/26/99*	*11/8/99*	*11/15/99*	*12/1/99*	*12/15/99*	*1/12/00*	*2/16/00*	*3/9/00*	*4/18/00*	*5/10/00*	*5/16/00*	*6/20/00*
Acidity	mg/l*			U	U	U	U	U	U		U	U	U	U	U
Dissolved Oxygen	mg/l			10.29	11.02	5.76	12.12	12.02	12.29		11.4	11.49	10	10.55	8.6
Dissolved Residue	mg/l			U	U	U	U	U	10		15	U	14	12	14
pH				4.77	5.6	4.47	5.69	4.93	4.46		5.3	5.31	5.31	5.2	5.18
Specific Conductivity	uMHO			18	18	22	19	20	22		16	16	17	17	18
Sulfate	mg/l			6	6	5	6	4	7		6	5	5	5	6
Suspended Residue	mg/l			U	U	U	U	U	U		U	U	U	U	U
Temperature	Celsius			7.7	10.6	9.6	4.8	7.7	6.0		10.0	11.4	15.3	12.37	17.7
Total Alkalinity	mg/l*			3	3	3	3	2	2		2	2	2	2	U
Total Dissolved Solids	g/l			0.01	0.013	0.014	0.013		0.14		0.016	0.011	0.01	0.011	0.012
Total Hardness	mg/l			9	12	9	10	7	10		7	6	7	7	7
Turbidity	NTU			U	0.3	0.2	U	0.3	0.8		0.3	U	0.4	U	0.2
Aluminum	ug/l			U	U	U	128	102	168		U	248	146	305	373
Calcium	mg/l			1.02	1.04	1.08	1.10	1.10	1.02		0.95	0.97	0.97	1.02	1.13
Copper	ug/l			U	U	U	U	U	U		U	U	U	U	U
Iron	ug/l			67	U	U	U	U	30		28	U	U	43	59
Lead	ug/l			U	U	U	U	U	U		U	U	U	U	U
Manganese	ug/l			26	23	31	U	17	16		44	49	46	34	29
Nickel	ug/l			U	U	U	U	U	U		U	U	14	U	U
Zinc	ug/l			6	U	U	4	3	5		6	5	6	4	7
Salinity	ppt			0	0.013	0.01	0.01		0.01		0.01	0.01	0	0.01	0.01
Flow	cfs		0.004	0.01	0.06	0.3	0.066	1.48	2.17		1.68	3.45	0.25	0.03	0.07

* mg/l $CaCO_3$

Table B-6 Crab Orchard Creek (COC-3) Monitoring Data

Crab Orchard Creek **36 00'14.1"N**
Catoosa - Downstream of Laurel Branch **84 39'18.7"W**
COC-3

Test	*Units*	*10/5/99*	*10/13/99*	*10/26/99*	*11/8/99*	*11/15/99*	*12/1/99*	*12/15/99*	*1/12/00*	*2/16/00*	*3/9/00*	*4/18/00*	*5/10/00*	*5/16/00*	*6/20/00*
Acidity	mg/l*		U	32	U	11	U	U	U		U	U	U	U	U
Dissolved Oxygen	mg/l		9.57	12.19	11.55	6.57	12.87	12.25	12.34		10.25	11.29	9.38	10.08	8.53
Dissolved Residue	mg/l		114	372	134	182	70	27	21		35	23	57	96	113
pH			5.15	3.96	5.9	4.64	6.29	6.45	5.2		5.82	5.66	5.25	4.85	4.84
Specific Conductivity	uMHO		181	487	198	274	143	55	47		43	37	83	137	156
Sulfate	mg/l		87	285	91	129	72	16	13		15	13	33	61	68
Suspended Residue	mg/l		U	U	U	U	U	U	U		U	U	U	U	U
Temperature	Celsius		16.8	6.8	10.3	8.9	3.2	6.9	5.1		10.4	12.0	18.7	15.79	21.86
Total Alkalinity	mg/l*		4	U	4	2	4	5	5		2	2	2	2	2
Total Dissolved Solids	g/l			0.32	0.126	0.181	0.094		0.028		0.031	0.024	0.05	0.09	0.1
Total Hardness	mg/l		84	246	97	139	71	22	17		18	15	40	68	71
Turbidity	NTU		0.5	0.1	1.3	0.4	0.9	2.4	1.3		0.9	1	0.1	0.2	0.5
Aluminum	ug/l		530	3740	457	1020	497	296	256		268	499	351	830	205
Calcium	mg/l		14.4	40.6	17.3	24.2	12.9	4.2	3.61		3.29	2.94	6.13	11.4	12.4
Copper	ug/l		5	1	U	1	U	U	U		U	U	U	U	U
Iron	ug/l		191	220	348	336	364	163	136		133	138	140	368	280
Lead	ug/l		U	U	U	U	U	U	U		U	U	U	U	U
Manganese	ug/l		2120	7480	2290	3470	1290	260	190		342	300	923	1800	1640
Nickel	ug/l		37	190	44	81	29	U	21		13	13	37	32	55
Zinc	ug/l		45	179	46	75	29	10	8		15	15	30	48	50
Salinity	ppt			0.2	0.126	0.13	0.07		0.02		0.02	0.02	0	0.07	0.07
Flow	cfs		2.36	0.26	1.38	0.51	1.13	31.99	50.71		38.5	64.76	8.55	5.81	2.77

* mg/l $CaCO_3$

Table B-7 Smith Branch Monitoring Data

Smith Branch **36 00'21.6"N**
Pete Berger Road (White Oak Road) **84 36'28.7"W**
SB-1

Test	*Units*	*10/5/99*	*10/13/99*	*10/26/99*	*11/8/99*	*11/15/99*	*12/1/99*	*12/15/99*	*1/12/00*	*2/16/00*	*3/9/00*	*4/18/00*	*5/10/00*	*5/16/00*	*6/20/00*
Acidity	mg/l*	12	10	12	16	12	U	U	U	U	U	U	U	U	U
Dissolved Oxygen	mg/l	8.38	8.43	10.66	9.77	5.01	12.28	11.71	12.02	12.02	10.75	11.08	9.66	10.57	8.59
Dissolved Residue	mg/l	141	117	139	107	122	78	46	37	34	49	36	67	99	111
pH		5.84	5.65	5.59	6.2	5.92	6.32	6.39	4.83	5.55	5.65	5.81	5.82	5.85	5.79
Specific Conductivity	uMHO	207	185	206	194	203	151	94	67	54	67	58	99	132	153
Sulfate	mg/l	94	77	110	97	98	79	28	22	22	28	23	39	56	65
Suspended Residue	mg/l	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Temperature	Celsius	12.9	15.9	7.2	13.2	9.6	4.9	7.9	6.1	8.0	12.0	12.2	18.0	14.83	19.5
Total Alkalinity	mg/l*	11	8	11	9	11	7	7	4	2	4	3	5	6	7
Total Dissolved Solids	g/l	0.132	0.122	0.137	0.126	0.132	0.098		0.043	0.035	0.043	0.037	0.06	0.09	0.1
Total Hardness	mg/l	95	87	96	88	104	73	36	25	24	31	24	47	61	71
Turbidity	NTU	0.9	0.8	0.9	0.7	1	0.1	1.4	1.8	2.5	1.1	0.8	0.3	0.2	1
Aluminum	ug/l	169	141	U	U	U	U	163	166	222	U	U	156	238	U
Calcium	mg/l	19.2	16.2	22.5	17.1	18.8	12.8	6.33	3.99	3.76	5.35	4.12	7.88	11.3	13.1
Copper	ug/l	U	U	U	1	U	U	U	U	U	U	U	U	U	U
Iron	ug/l	816	657	861	664	806	528	208	209	224	313	247	371	529	546
Lead	ug/l	U	U	U	U	U	U	U	U	U	U	U	5	U	U
Manganese	ug/l	762	943	798	916	863	649	333	199	217	325	274	510	794	740
Nickel	ug/l	11	26	20	U	U	U	U	U	10	12	U	15	U	11
Zinc	ug/l	16	20	20	11	7	14	8	8	12	9	11	11	12	12
Salinity	ppt	0.10	0.09	0.10		0.10	0.07		0.03	0.02	0.03	0.02	0.10	0.1	0.1
Flow	cfs	0.09	0.22	0.15	0.23	0.12	0.13	2.13	4.11	13.51	2.66	4.34	0.98	0.53	0.32

* mg/l $CaCO_3$

Table B-8 Crab Orchard Creek (COC-2) Monitoring Data

Crab Orchard Creek **36 00'40.1"N**
Deer Mont Road **84 36'38.2"W**
COC-2

Test	*Units*	*10/5/99*	*10/13/99*	*10/26/99*	*11/8/99*	*11/15/99*	*12/1/99*	*12/15/99*	*1/12/00*	*2/16/00*	*3/9/00*	*4/18/00*	*5/10/00*	*5/16/00*	*6/20/00*
Acidity	mg/l*	U	10	U	U	U	U	U	U	U	U	U	U	U	U
Dissolved Oxygen	mg/l	10.01	9.50	11.90	11.60	5.70	13.07	12.26	12.41	12.37	11.02	11.21	9.17	9.69	8.4
Dissolved Residue	mg/l	170	155	171	131	135	86	30	24	13	35	27	54	76	87
pH		6.24	5.01	5.88	5.3	5.57	5.74	6.47	5.3	6.11	5.94	5.97	5.8	5.91	5.72
Specific Conductivity	uMHO	252	241	249	217	221	161	64	48	31	45	43	78	106	126
Sulfate	mg/l	126	111	123	107	109	85	19	12	11	19	17	32	43	56
Suspended Residue	mg/l	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Temperature	Celsius	15.5	17.4	10.7	12.2	11.0	3.7	7.2	5.2	7.7	11.6	12.8	21.1	18.98	24.15
Total Alkalinity	mg/l*	6	2	5	3	3	2	5	4	3	3	2	2	3	3
Total Dissolved Solids	g/l	0.163	0.156	0.162	0.139	0.143	0.104		0.31	0.021	0.031	0.028	0.05	0.069	0.08
Total Hardness	mg/l	125	118	126	106	108	82	24	18	16	20	21	41	51	60
Turbidity	NTU	0.2	U	0.3	U	0.2	0.1	1.2	0.7	1.6	0.1	0.7	U	0.5	U
Aluminum	ug/l	201	627	272	482	300	934	222	144	212	182	143	191	661	304
Calcium	mg/l	23.4	21.5	22.8	19.7	19.5	13.4	4.48	3.44	2.58	4.24	3.32	6.02	9.37	10.8
Copper	ug/l	U	U	U	U	U	U	U	U	U	1	U	U	U	U
Iron	ug/l	224	101	288	135	234	120	127	74	119	84	69	45	587	64
Lead	ug/l	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Manganese	ug/l	323	1230	467	790	498	448	189	118	138	247	270	324	448	413
Nickel	ug/l	U	59	37	35	38	11	U	U	U	15	U	20	U	19
Zinc	ug/l	24	70	46	43	35	33	8	6	9	11	16	18	24	38
Salinity	ppt	0.12	0.12	0.12	0.1	0.11	0.08		0.02	0.01	0.02	0.02	0	0.05	0.1
Flow	cfs	0.56	2.33	0.6	2.16	1.23	1.48	34.12	49.61	146.83	40.39	69.29	11.12	4.56	4.62

* mg/l $CaCO_3$

Table B-9 Mill Creek Monitoring Data

Mill Creek **36 01'36.1"N**
Deer Mont Road **84 35'18.5"W**
MC-1

Test	*Units*	*10/5/99*	*10/13/99*	*10/26/99*	*11/8/99*	*11/15/99*	*12/1/99*	*12/15/99*	*1/12/00*	*2/16/00*	*3/9/00*	*4/18/00*	*5/10/00*	*5/16/00*	*6/20/00*
Acidity	mg/l*	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Dissolved Oxygen	mg/l	10.55	9.88	12.52	10.59	4.78	13.21	13.13	12.31	12.05	11.98	11.54	9.45	10.13	8.64
Dissolved Residue	mg/l	411	261	342	259	290	189	79	60	27	53	48	90	143	180
pH		6.72	6.57	6.07	7.00	7.12	7.1	6.03	5.66	5.98	6.26	6.36	6.4	6.53	6.62
Specific Conductivity	uMHO	538	382	461	381	421	296	150	109	44	75	81	132	191	250
Sulfate	mg/l	289	178	244	192	212	146	50	39	17	32	30	55	90	125
Suspended Residue	mg/l	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Temperature	Celsius	14.6	16.7	10.4	12.7	11.3	3.8	8.0	5.5	8.8	12.0	12.3	20.3	17.61	23.81
Total Alkalinity	mg/l*	24	17	22	16	19	11	5	4	2	3	3	6	8	12
Total Dissolved Solids	g/l	0.350	0.248	0.300	0.248	0.273	0.193		0.067	0.029	0.048	0.044	0.090	0.124	0.162
Total Hardness	mg/l	296	196	257	210	228	148	62	41	20	37	34	66	101	128
Turbidity	NTU	U	U	U	0.1	U	0.1	0.3	0.8	1.6	0.4	0.4	0.1	U	0.4
Aluminum	ug/l	U	U	U	U	U	706	124	130	138	U	U	183	U	525
Calcium	mg/l	59.2	19.4	32.9	30.8	36.1	23.6	9.96	6.18	3.02	5.6	4.97	9.8	16.2	19.6
Copper	ug/l	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Iron	ug/l	80	51	46	60	28	78	70	73	122	74	54	78	82	121
Lead	ug/l	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Manganese	ug/l	25	65	48	71	69	66	137	102	124	116	115	83	98	42
Nickel	ug/l	16	U	U	U	U	U	U	U	U	U	U	U	U	U
Zinc	ug/l	6	3	5	U	U	5	3	7	4	2	4	3	3	3
Salinity	ppt	0.26	0.18	0.2	0.18	0.2	0.14		0.05	0.02	0.04	0.03	0.1	0.09	0.12
Flow	cfs	0.27	0.59	0.24	0.61	0.03	0.28	7.91	11.57	37.87	9.25	13.28	2.08	1.07	0.7

* mg/l $CaCO_3$

Table B-10 Crab Orchard Creek (COC-1) Monitoring Data

Crab Orchard Creek **36 01'15.6"N**
Downstream of Mill Creek **84 34'56.4"W**
COC-1

Test	*Units*	*10/5/99*	*10/13/99*	*10/26/99*	*11/8/99*	*11/15/99*	*12/1/99*	*12/15/99*	*1/12/00*	*2/16/00*	*3/9/00*	*4/18/00*	*5/10/00*	*5/16/00*	*6/20/00*
Acidity	mg/l*	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Dissolved Oxygen	mg/l	10.07	9.69	12.88	11.83	3.38	13.38	13.09	12.47	12.21	11.03	11.29	9.13	9.78	8.4
Dissolved Residue	mg/l	180	190	187	119	144	100	45	34	19	41	33	55	77	100
pH		6.84	6.11	6.44	6.4	6.83	6.51	6.02	5.9	6.27	6.3	6.42	6.47	6.59	6.55
Specific Conductivity	uMHO	265	286	266	268	246	193	83	61	36	52	50	86	113	145
Sulfate	mg/l	116	134	138	131	107	94	25	19	12	20	19	37	48	68
Suspended Residue	mg/l	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Temperature	Celsius	15.6	17.8	7.4	11.2	9.5	2.8	7.5	5.3	8.5	12.2	13.0	21.8	19.25	24.79
Total Alkalinity	mg/l*	12	4	6	5	7	5	5	6	3	3	3	4	5	5
Total Dissolved Solids	g/l	0.172	0.186	0.174	0.174	0.16	0.125		0.038	0.023	0.034	0.033	0.06	0.07	0.09
Total Hardness	mg/l	132	141	133	132	123	94	32	22	16	23	22	40	54	76
Turbidity	NTU	U	U	U	U	U	0.1	1.4	0.6	1.8	0.6	0.5	U	0.9	U
Aluminum	ug/l	U	366	U	149	U	565	240	123	178	U	U	159	U	U
Calcium	mg/l	23.2	25.8	22.7	23.4	22	15.8	5.69	4.03	2.74	4.34	3.82	6.95	9.52	12.6
Copper	ug/l	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Iron	ug/l	37	32	42	U	U	26	106	57	108	52	49	38	35	60
Lead	ug/l	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Manganese	ug/l	16	1080	34	603	106	320	155	95	130	198	211	156	134	74
Nickel	ug/l	U	35	U	35	11	U	U	U	12	U	U	11	U	U
Zinc	ug/l	11	56	7	29	2	23	3	5	8	11	10	9	8	10
Salinity	ppt	0.13	0.14	0.13	0.13	0.12	0.09		0.03	0.02	0.03	0.02	0	0.1	0.1
Flow	cfs	0.76	3.81	0.78	3.01	1.61	1.46	40.46	60.45	207.43	49.44	99.75	15.63	8.14	6.17

* mg/l $CaCO_3$

APPENDIX C

Biorecon of Crab Orchard Creek Section Used as Target

Table C-1 Benthic Biorecon of Crab Orchard Creek Upstream of COC-4

BENTHIC BIORECON DATASHEET

Storet #
Stream Name: Crab Orchard Creek
Location: u/s COC-4
County: Cumberland

Assessors: JEB/JCP/LEE
Date: 5/18/01
Time: 9:40-11:15
Waterbody I.D.#: 06010208-020

Habitats: Cobble/rock vegetation/moss; Banks; Leaf packs; Woody debris, snags; Sediment

	Organisms	#	TI	#xTI	TCR
Oligochaeta				0	
				0	
Hirudinea				0	
				0	
Isopoda				0	
				0	
Amphipoda				0	
				0	
Decapoda	*Astacidae*	1	7.5	7.5	
				0	
Ephemeroptera	*Acentrella*	8	3.6	28.8	
	Centroptilum	9	6.6	59	
	Procloeon	18	5	90	
	Baetis	3	4.51	13.53	
	Eurylophella	18	4.34	78.12	
	Timpanoga	1	1.8	1.8	
	Stenonema	5	3.45	17.25	
	Leucrocuta	1	2.4	2.4	
	Epeorus	2	1.27	2.54	
	Stenacron	9	3.58	32.22	
	Heptagenia	5	2.57	12.85	
	Paraleptophlebia	3	0.94	2.82	
	Isonychia	1	3.45	3.45	
	Habrophlebia	3	0	0	
Plecoptera	*Acroneuria*	5	1.47	7.35	
	Agnetina	3	1.5	4.5	
				0	
	Amphinemura	5	3.33	16.65	
	Leuctra	2	0.67	1.34	
Tricoptera	*Cheumatopsyche*	4	6.22	24.88	
	Glossosoma	5	1.55	7.75	
	Lepidostoma	2	0.9	1.8	
	Pycnopsyche	3	2.52	7.56	
	Oecetis	1	4.7	4.7	
	Dolophilodes	1	0.81	0.81	
				0	
Hemiptera				0	
				0	
		118		430	

	Organisms	#	TI	#xTI	TCR
Odonata	*Boyeria*	2	5.97	11.9	
	Helocordulia	1	4.83	4.83	
	Neurocordulia	1	5.03	5.03	
				0	
				0	
Megaloptera	*Nigronia*	1	5.25	5.25	
				0	
Coleoptera	*Psephenus*	3	2.35	7.05	
	Copelatus	1	9.2	9.2	
	Dubiraphia	1	5.93	5.93	
	Oulimnius	1	1.8	1.8	
	Optioservus	5	2.36	11.8	
				0	
Diptera	*Simulium*	16	4	64	
	Tanypodinae	6	5.39	32.3	
	Tanytarsini	8	3.85	30.8	
	Chironomini	5	5.99	30	
	Orthocladinae	7	4.18	29.3	
	Chironomidae pupae	1	6	6	
	Antocha	1	4.25	4.25	
	Hexatoma	2	4.31	8.62	
	Bezzia	3	6	18	
				0	
				0	
				0	
				0	
Gastropoda				0	
	Ferrissia	2	6.55	13.1	
				0	
Pelecypoda				0	
				0	
				0	
Other	*Acari*	2	5.53	11.1	
				0	
				0	
				0	
				0	
		69		310	

Taxa Richness	44
EPT taxa	24
Intolerant Taxa	22
Tolerance Index	3.96

total # organisms = 187
Sum of #XTI = 740

Table C-2 Fish Collected from Crab Orchard Creek Upstream of COC-4

Fish collected from Crab Orchard Creek, Cumberland County, 2nd bridge u/s of COC-4, app. 1 mile u/s of Morgan County border, on May 18, 2001.

Common Name	Scientific Name	Number	Tolerance	Trophic Guild	Family Group	Anomalies
Central Stoneroller	*Campostoma anomalum*	33		Herbivore	Misc	
Creek Chub	*Semotilus atromaculatus*	41	TOL	Insectivore	Misc	15
Blacknose Dace	*Rhinichthys atratulus*	6		Specialist	Misc	1
Whitetail Shiner	*Cyprinella galactura*	145		Specialist	Misc	
Spotfin Shiner	*Cyprinella spiloptera*	7	TOL	Insectivore	Misc	
Sand Shiner	*Notropis stramineus*	1		Specialist	Misc	
Northern Hogsucker	*Hypentelium nigricans*	11		Insectivore	Sucker	
White Sucker	*Catostomus commersoni*	8	TOL	Insectivore	Sucker	1
Rock Bass	*Ambloplites rupestris*	34 (5 were >5")	INT	Piscivore	Sunfish	5
Bluegill	*Lepomis macrochirus*	7		Insectivore	Sunfish	
Green Sunfish	*Lepomis cyanellus*	3	TOL	Piscivore	Sunfish	
Hybrid Sunfish	*Lepomis spp.*	1		Insectivore	Sunfish	
Smallmouth Bass	*Micropterus dolomieu*	4		Piscivore	Misc	
Stripetail Darter	*Etheostoma kennecotti*	45		Specialist	Darter	
Redline Darter	*Etheostoma rufilineatum*	2		Specialist	Darter	
Greenside Darter	*Etheostoma blenniodes*	2		Specialist	Darter	1
		350				23

APPENDIX D

Development of Target Load Duration Curve for Crab Orchard Creek Subwatershed

Development of Target Load-Duration Curve

The target net alkalinity load-duration curve for the unimpaired section of the Crab Orchard Creek subwatershed (upstream of Golliher Creek) was developed from the flow-duration curve of the Emory River at USGS continuous record station 03540500 at Oakdale (RM 18.3), the appropriate drainage areas, and monitoring data collected in 1999 & 2000 using the following procedure:

1. A flow-duration curve for USGS 03540500 (see Figure D-1) was constructed using daily mean flows for the 12 year period from 10/1/88 through 9/30/00. (The largest daily mean flow during this period is exceeded 0% of the time and the smallest daily mean flow is exceeded ~100% of the time). USGS 03540500 is a continuous record station located at RM 18.3 of the Emory River, approximately three miles downstream of Crab Orchard Creek.

2. Each ranked daily mean flow was divided by the drainage area upstream of the USGS station to create a flow-duration curve on a unit drainage area basis. (There is, therefore, a "percent of days that the flow per unit area is exceeded" associated with each of the 4,383 measured daily mean flows per unit area). This was used as the foundation for subsequent flow/load-duration curves for Crab Orchard Creek and its tributaries (see Figure D-2).

3. Sampling was conducted at several sites in the Crab Orchard Creek subwatershed between 10/5/99 and 6/20/00 (see Figure 3). Data collected included: flow, pH, acidity, & total alkalinity. The net alkalinity for each sampling event at the COC-4 site was calculated from the measured data (Table D-1). Using a value of ½ the quantitation limit for samples reported as "not detected", the average net alkalinity for the COC-4 drainage area was determined to be 11.2 mg/l $CaCO_3$.

4. The target load-duration curve (on a unit drainage area basis) was generated by applying the average net alkalinity at COC-4 to each of the 4,383 ranked flows per unit drainage area:

   $$\text{Target Load}_{COC\text{-}4} = (\text{Average Net Alkalinity})_{COC\text{-}4} \times (Q/A) \times (UCF)$$

   where: Q = daily mean flow
   A = drainage area
   UCF = the required unit conversion factor

   The target load-duration curve, on a unit drainage area basis, is presented in Figures D-3 & 4. The figures represent the same information, except that Figure D-3 is presented in a semi-log scale format while Figure D-4 is presented in a non-log scale format. Since the calculated net alkalinity of Crab Orchard Creek subwatersheds is often negative, the non-log scale format will be used in this TMDL.

Table D-1 Calculated Net Alkalinity at COC-4

Sample Date	Flow	Acidity	Total Alkalinity	Net Alkalinity
	[cfs]	[mg/l][b]	[mg/l][b]	[mg/l][b]
10/5/99	0.11	5[a]	29	24
10/13/99	0.71	5[a]	30	25
10/26/99	0.32	5[a]	26	21
11/8/99	1.19	5[a]	25	20
11/15/99	0.62	5[a]	25	20
12/1/99	0.92	5[a]	20	15
12/15/99	18.98	5[a]	8	3
1/12/00	26.45	5[a]	7	2
2/16/00	83.86	5[a]	5	0
3/9/00	22.77	5[a]	6	1
4/18/00	41.41	5[a]	5	0
5/10/00	6.54	5[a]	9	4
5/16/00	1.65	5[a]	12	7
6/20/00	1.59	5[a]	20	15
6/20/00	1.59	5[a]	20	11.2

a Reported as not detected; value shown is ½ sample quantitation limit.
b Acidity, total alkalinity, & net alkalinity are reported as mg/l $CaCO_3$.

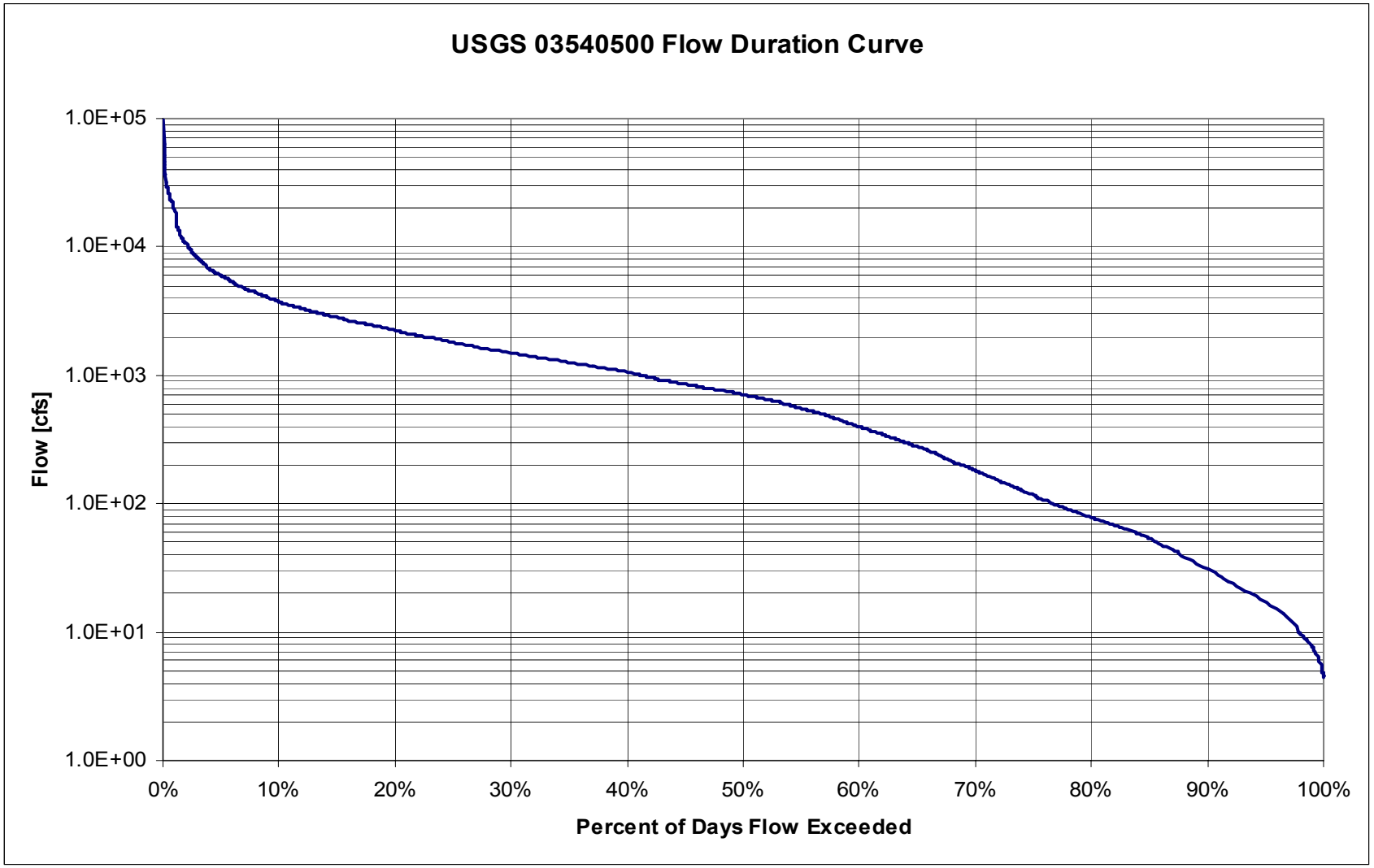

Figure D-1 USGS 03540500 Flow-Duration Curve

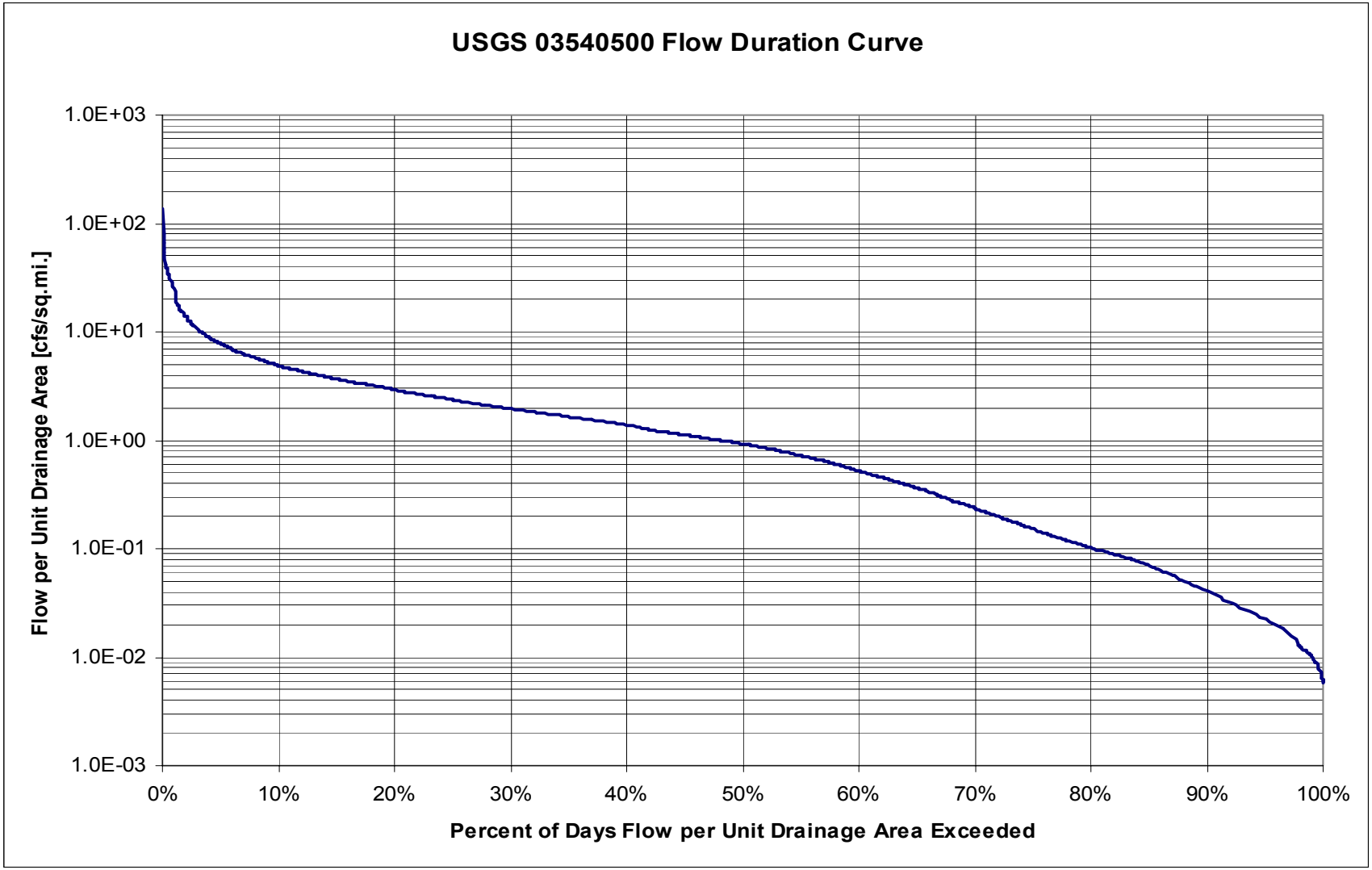

Figure D-2 USGS 03540500 Flow-Duration Curve per Unit Drainage Area

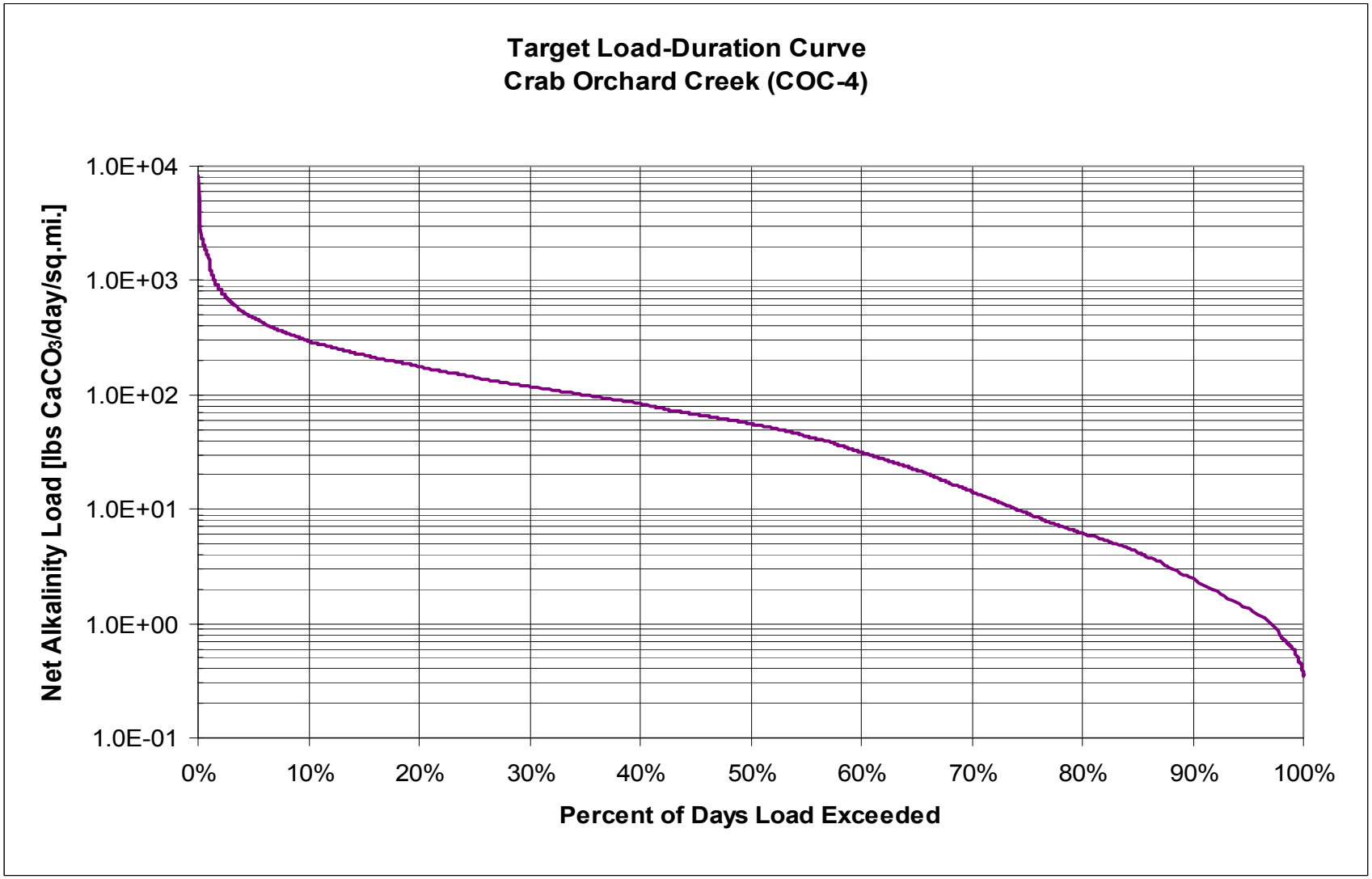

Figure D-3 Target Load-Duration Curve for Crab Orchard Creek Subwatershed (Semi-Log Scale)

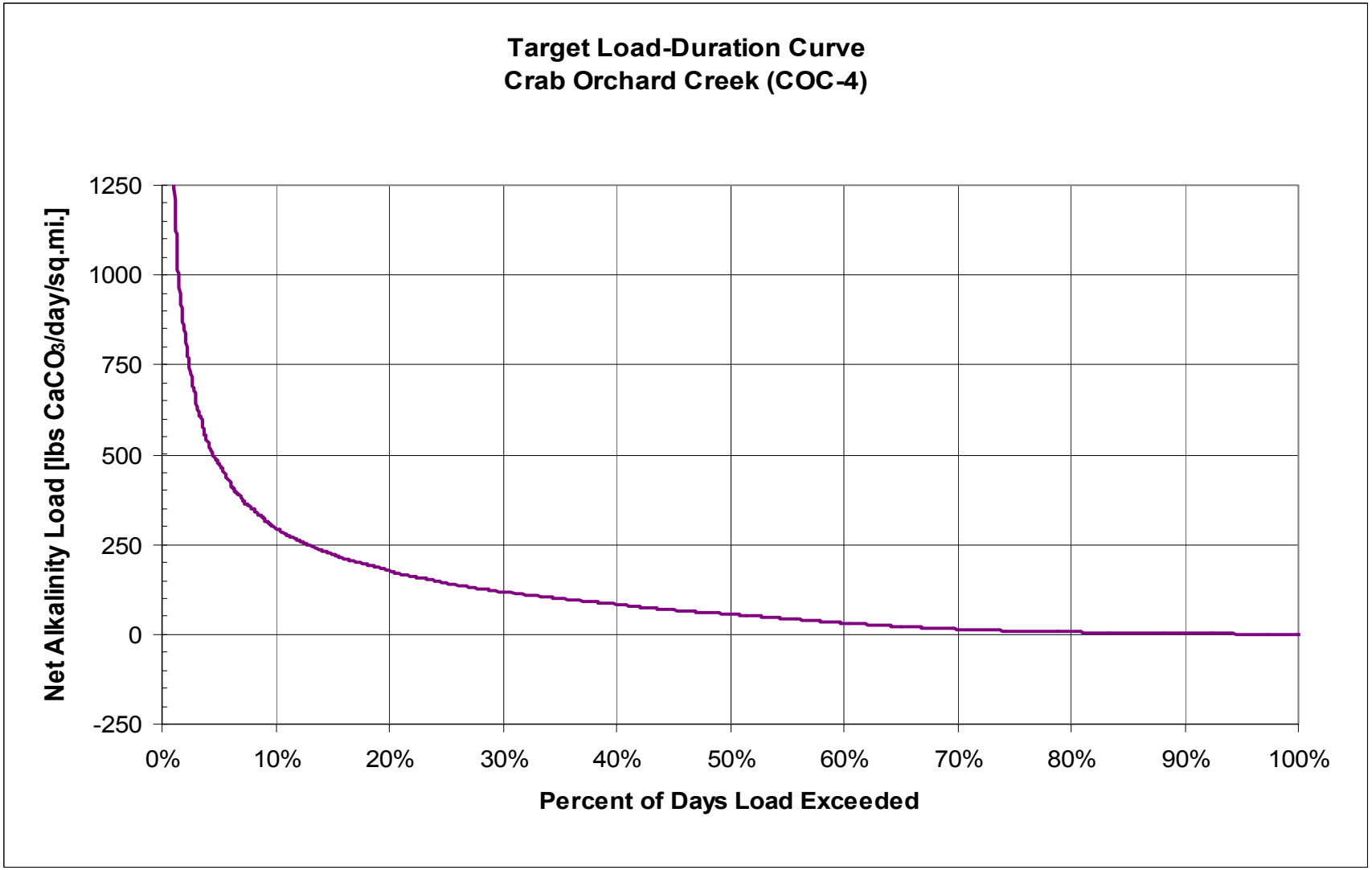

Figure D-4 Target Load-Duration Curve for Crab Orchard Creek Subwatershed

APPENDIX E

Methodology for the Determination of Subwatershed Net Alkalinity Difference From Target Load-Duration Curve

Methodology for the Determination of Subwatershed Net Alkalinity Difference from Target Load-Duration Curve

Sampling was conducted at several sites in the Crab Orchard Creek subwatershed between 10/5/99 and 6/20/00 (ref: Figure 3). Data collected included: flow, pH, acidity, & total alkalinity (ref: Table 3). The calculation of net alkalinity for each sampling event and the determination of the difference from the target load-duration curve developed in Appendix D was performed for Golliher Creek using the following methodology (other subwatersheds are similar):

For each sampling event:

1. The net alkalinity and stream flow per unit drainage area were calculated from monitoring data and are summarized in Table E-1. The drainage area of the Golliher Creek subwatershed, upstream of Station GC-1 is approximately 2.928 mi^2.

$$\text{Net Alkalinity}_{\text{Mass/Area}} = (\text{Net Alkalinity}_{\text{Conc.}}) \times (Q/A)_{\text{GC-1}} \times (\text{UCF})$$

where: $[\text{Net Alkalinity}]_{\text{Mass/Area}}$ = Net alkalinity amount [lbs $CaCO_3$/day/mi^2]
$[\text{Net Alkalinity}]_{\text{Conc}}$ = Net alkalinity [mg $CaCO_3$/l]
Q = Golliher Creek estimated flow on sample date [cfs]
A = Golliher Creek drainage area [mi^2]
UCF = required unit conversion factor

Table E-1 Golliher Creek Calculated Net Alkalinity

Sample Date	Golliher Ck. Flow At GC-1		Acidity	Total Alkalinity	Net Alkalinity	
	[cfs]	[cfs/mi^2]	[mg/l][b]	[mg/l][b]	[mg/l][b]	[lbs/day/mi^2][b]
10/5/99	0.072	0.025	102	0.5[a]	-101.5	-13.46
10/13/99	0.23	0.079	96	0.5[a]	-95.5	-40.45
10/26/99	0.16	0.055	113	0.5[a]	-112.5	-33.15
11/8/99	0.282	0.096	99	0.5[a]	-98.5	-51.15
11/15/99	0.12	0.041	97	0.5[a]	-96.5	-21.32
12/1/99	0.092	0.031	68	0.5[a]	-67.5	-11.44
12/15/99	3.34	1.141	20	0.5[a]	-19.5	-119.9
1/12/00	4.31	1.472	15	0.5[a]	-14.5	-115.1
2/16/00	14.66	5.007	16	0.5[a]	-15.5	-418.4
3/9/00	3.6	1.230	18	0.5[a]	-17.5	-116.0
4/18/00	3.8	1.298	19	0.5[a]	-18.5	-129.5
5/10/00	1.24	0.424	34	0.5[a]	-33.5	-76.49
5/16/00	0.18	0.062	52	0.5[a]	-51.5	-17.07
6/20/00	0.27	0.092	51	0.5[a]	-50.5	-25.11

a Reported as not detected; value shown is ½ sample quantitation limit.
b Acidity, total alkalinity, & net alkalinity are reported as mg/l $CaCO_3$ or lbs $CaCO_3$/day/mi^2

2. Using the flow duration curve per unit area developed in Appendix D for USGS Station No.03540500 (ref: Figure D-2) and the Golliher Creek flow per unit area (ref: Table E-1), the "percent of days the flow per unit area was exceeded" (PDFE) was determined for each sampling event.

   Example – 12/15/99 sampling event:

   Golliher Creek flow per unit area = 1.1407 cfs/mi^2
   PDFE from Figure D-2 corresponding to 1.1407 cfs/mi^2 = 44.40%

3. The target net alkalinity load was determined using the PDFE and the target load-duration curve developed in Appendix D (ref: Figure D-4).

   Example – 12/15/99 sampling event:

   Target net alkalinity load corresponding to a PDFE of 44.40% = 69.0 lbs $CaCO_3$/day/mi^2

4. The magnitude of the difference between the target net alkalinity load and the calculated net alkalinity load is calculated by:

   $$\text{Net Alkalinity}_{\text{Difference}} = (\text{Net Alkalinity}_{\text{Golliher}}) - (\text{Net Alkalinity}_{\text{Target}})$$

   where:
   Net Alkalinity is in lbs $CaCO_3$/day/mi^2

   Example – 12/15/99 sampling event:

   Golliher Creek net alkalinity = -119.9 lbs $CaCO_3$/day/mi^2

   $\text{Net Alkalinity}_{\text{Difference}}$ = (-119.9 lbs $CaCO_3$/day/mi^2) - (69.0 lbs $CaCO_3$/day/mi^2)

   $\text{Net Alkalinity}_{\text{Difference}}$ = -188.9 lbs $CaCO_3$/day/mi^2

   The negative sign indicates that the Golliher Creek net alkalinity load must be <u>increased</u> to meet the target.

5. The difference between the target net alkalinity load and the calculated net alkalinity load for all of the Golliher Creek sampling events is summarized in Table E-2 and illustrated in Figure E-1.

Table E-2 Net Alkalinity Difference - Golliher Creek Relative to Target

Sample Event Date	Golliher Ck. Flow	Golliher Ck. Net Alkalinity Load	PDFE[a]	Target Net Alkalinity Load	Net Alkalinity Load Difference
	[cfs/mi^2]	[lbs/day/mi^2][b]	[%]	[lbs/day/mi^2][b]	[lbs/day/mi^2][b]
10/5/99	0.025	-13.46	94.2	1.50	-15.0
10/13/99	0.079	-40.45	83.8	4.74	-45.2
10/26/99	0.055	-33.15	87.4	3.32	-36.5
11/8/99	0.096	-51.15	81.0	5.77	-56.9
11/15/99	0.041	-21.32	90.0	2.45	-23.8
12/1/99	0.031	-11.44	92.2	1.90	-13.3
12/15/99	1.141	-119.9	44.4	69.00	-188.9
1/12/00	1.472	-115.1	38.4	88.53	-203.6
2/16/00	5.007	-418.4	9.7	302.7	-721.1
3/9/00	1.230	-116.0	42.5	74.22	-190.2
4/18/00	1.298	-129.5	41.4	78.49	-207.9
5/10/00	0.424	-76.49	62.9	25.53	-102.0
5/16/00	0.062	-17.07	86.2	3.72	-20.8
6/20/00	0.092	-25.11	81.6	5.53	-30.6

a Percent of Days Flow Is Exceeded
b Net alkalinity is reported as lbs $CaCO_3$/day/mi^2

6. For other subwatersheds, monitoring data, net alkalinity, and difference from target loads are summarized in Tables E-3 through E-18. Difference from target loads are illustrated in Figures E-2 to E-10.

Table E-3 Fagan Mill Creek Calculated Net Alkalinity

Sample Date	Fagan Mill Ck. Flow At FM-1		Acidity	Total Alkalinity	Net Alkalinity	
	[cfs]	[cfs/mi^2]	[mg/l][b]	[mg/l][b]	[mg/l][b]	[lbs/day/mi^2][b]
10/5/99	0.001	0.0007	152	0.5[a]	-151.5	-0.555
10/13/99	0.01	0.007	86	0.5[a]	-85.5	-3.132
10/26/99	0.02	0.014	125	0.5[a]	-124.5	-9.121
11/8/99	0.063	0.043	54	0.5[a]	-53.5	-12.35
11/15/99	0.33	0.224	67	0.5[a]	-66.5	-80.38
12/1/99	0.043	0.029	24	0.5[a]	-23.5	-3.701
12/15/99	1.97	1.338	5[a]	3	-2	-14.43
1/12/00	2.59	1.760	5[a]	3	-2	-18.97
2/16/00	7.73	5.251	12	2	-10	-283.1
3/9/00	1.64	1.114	5[a]	2	-3	-18.02
4/18/00	3.61	2.452	15	0.5[a]	-14.5	-191.7
5/10/00	0.61	0.414	23	0.5[a]	-22.5	-50.27
5/16/00	0.22	0.149	45	0.5[a]	-44.5	-35.86
6/20/00	0.12	0.082	50	0.5[a]	-49.5	-21.76

a Reported as not detected; value shown is ½ sample quantitation limit.
b Acidity, total alkalinity, & net alkalinity are reported as mg/l $CaCO_3$ or lbs $CaCO_3$/day/mi^2.

Table E-4 Net Alkalinity Difference – Fagan Mill Creek Relative to Target

Sample Event Date	Fagan Mill Ck. Flow	Fagan Mill Ck. Net Alkalinity Load	PDFE[a]	Target Net Alkalinity Load	Magnitude Of Difference
	[cfs/mi^2]	[lbs/day/mi^2][b]	[%]	[lbs/day/mi^2][b]	[lbs/day/mi^2][b]
10/5/99	0.0007	-0.555	100	0.348	-0.903
10/13/99	0.007	-3.132	99.9	0.411	-3.54
10/26/99	0.014	-9.121	97.9	0.790	-9.91
11/8/99	0.043	-12.35	89.4	2.61	-15.0
11/15/99	0.224	-80.38	70.6	13.5	-93.9
12/1/99	0.029	-3.701	92.8	1.74	-5.44
12/15/99	1.338	-14.43	40.9	80.6	-95.1
1/12/00	1.760	-18.97	33.3	105.9	-124.9
2/16/00	5.251	-283.1	9.1	317.0	-600.1
3/9/00	1.114	-18.02	45.1	67.3	-85.3
4/18/00	2.452	-191.7	24.3	147.8	-339.5
5/10/00	0.414	-50.27	63.2	25.1	-75.3
5/16/00	0.149	-35.86	75.2	9.01	-44.9
6/20/00	0.082	-21.76	83.4	4.90	-26.7

a Percent of Days Flow Is Exceeded.
b Net alkalinity is reported as lbs $CaCO_3$/day/mi^2.

Table E-5 Little Laurel Creek Calculated Net Alkalinity

Sample Date	Little Laurel Ck. Flow At LLC-1		Acidity	Total Alkalinity	Net Alkalinity	
	[cfs]	[cfs/mi^2]	[mg/l][b]	[mg/l][b]	[mg/l][b]	[lbs/day/mi^2][b]
10/5/99	—	—	—	—	—	—
10/13/99	—	—	—	—	—	—
10/26/99	—	—	—	—	—	—
11/8/99	—	—	—	—	—	—
11/15/99	—	—	—	—	—	—
12/1/99	0.016	0.018	14	3	-11	-1.088
12/15/99	0.59	0.677	12	2	-10	-36.48
1/12/00	0.81	0.929	5[a]	3	-2	-10.02
2/16/00	4.15	4.759	5[a]	2	-3	-76.98
3/9/00	1.46	1.674	5[a]	2	-3	-27.08
4/18/00	2.02	2.317	5[a]	2	-3	-37.47
5/10/00	0.24	0.275	5[a]	3	-2	-2.968
5/16/00	0.09	0.103	17	2	-15	-8.347
6/20/00	0.03	0.034	16	5	-11	-2.040

a Reported as not detected; value shown is ½ sample quantitation limit.
b Acidity, total alkalinity, & net alkalinity are reported as mg/l $CaCO_3$ or lbs $CaCO_3$/day/mi^2.

Table E-6 Net Alkalinity Difference – Little Laurel Creek Relative to Target

Sample Event Date	Little Laurel Ck. Flow	Little Laurel Ck. Net Alkalinity Load	PDFE[a]	Target Net Alkalinity Load	Magnitude Of Difference
	[cfs/mi^2]	[lbs/day/mi^2][b]	[%]	[lbs/day/mi^2][b]	[lbs/day/mi^2][b]
10/5/99	—	—	—	—	—
10/13/99	—	—	—	—	—
10/26/99	—	—	—	—	—
11/8/99	—	—	—	—	—
11/15/99	—	—	—	—	—
12/1/99	0.018	-1.088	96.5	1.11	-2.19
12/15/99	0.677	-36.48	56.2	40.9	-77.3
1/12/00	0.929	-10.02	50.0	56.0	-66.1
2/16/00	4.759	-76.98	10.3	287.7	-364.7
3/9/00	1.674	-27.08	34.5	101.2	-128.3
4/18/00	2.317	-37.47	25.3	139.9	-177.4
5/10/00	0.275	-2.968	68.1	16.6	-19.6
5/16/00	0.103	-8.347	79.8	6.24	-14.6
6/20/00	0.034	-2.040	91.2	2.13	-4.17

a Percent of Days Flow Is Exceeded.
b Net alkalinity is reported as lbs $CaCO_3$/day/mi^2.

Table E-7 Laurel Creek Calculated Net Alkalinity

Sample Date	Laurel Ck. Flow At LB-1-1		Acidity	Total Alkalinity	Net Alkalinity	
	[cfs]	[cfs/mi^2]	[mg/l][b]	[mg/l][b]	[mg/l][b]	[lbs/day/mi^2][b]
10/5/99	—	—	—	—	—	—
10/13/99	0.004	0.003	—	—	—	—
10/26/99	0.01	0.007	5[a]	3	-2	-0.074
11/8/99	0.06	0.041	5[a]	3	-2	-0.443
11/15/99	0.3	0.205	5[a]	3	-2	-2.21
12/1/99	0.066	0.045	5[a]	23	-2	-0.487
12/15/99	1.48	1.013	5[a]	2	-3	-16.39
1/12/00	2.17	1.485	5[a]	2	-3	-24.03
2/16/00	—	—	—	—	—	—
3/9/00	1.68	1.150	5[a]	2	-3	-18.60
4/18/00	3.45	2.361	5[a]	2	-3	-38.20
5/10/00	0.25	0.171	5[a]	2	-3	-2.77
5/16/00	0.03	0.021	5[a]	2	-3	-0.332
6/20/00	0.07	0.048	5[a]	0.5[a]	-4.5	-1.16

a Reported as not detected; value shown is ½ sample quantitation limit.
b Acidity, total alkalinity, & net alkalinity are reported as mg/l $CaCO_3$ or lbs $CaCO_3$/day/mi^2.

Table E-8 Net Alkalinity Difference – Laurel Creek Relative to Target

Sample Event Date	Laurel Ck. Flow	Laurel Ck. Net Alkalinity Load	PDFE[a]	Target Net Alkalinity Load	Magnitude Of Difference
	[cfs/mi^2]	[lbs/day/mi^2][b]	[%]	[lbs/day/mi^2][b]	[lbs/day/mi^2][b]
10/5/99	—	—	—	—	—
10/13/99	0.003	—	—	—	—
10/26/99	0.007	-0.074	99.8	0.419	-0.493
11/8/99	0.041	-0.443	90.0	2.45	-2.89
11/15/99	0.205	-2.21	71.6	12.4	-14.6
12/1/99	0.045	-0.487	88.9	2.77	-3.25
12/15/99	1.013	-16.39	47.7	61.1	-77.5
1/12/00	1.485	-24.03	38.3	89.3	-113.3
2/16/00	—	—	—	—	—
3/9/00	1.150	-18.60	44.3	69.5	-88.1
4/18/00	2.361	-38.20	25.1	142.3	-180.5
5/10/00	0.171	-2.77	73.7	10.4	-13.1
5/16/00	0.021	-0.332	95.4	1.26	-1.60
6/20/00	0.048	-1.16	88.5	2.92	-4.09

a Percent of Days Flow Is Exceeded.
b Net alkalinity is reported as lbs $CaCO_3$/day/mi^2.

Table E-9 Crab Orchard Creek (COC-3) Calculated Net Alkalinity

Sample Date	Crab Orchard Creek Flow at COC-3		Acidity	Total Alkalinity	Net Alkalinity	
	[cfs]	[cfs/mi^2]	[mg/l][b]	[mg/l][b]	[mg/l][b]	[lbs/day/mi^2][b]
10/5/99	—	—	—	—	—	—
10/13/99	2.36	0.079	5[a]	4	-1	-0.427
10/26/99	0.26	0.009	32	0.5[a]	-31.5	-1.48
11/8/99	1.38	0.046	5[a]	4	-1	-0.249
11/15/99	0.51	0.017	11	2	-9	-0.830
12/1/99	1.13	0.038	5[a]	4	-1	-0.204
12/15/99	31.99	1.072	5[a]	5	0	0
1/12/00	50.71	1.700	5[a]	5	0	0
2/16/00	—	—	—	—	—	—
3/9/00	38.50	1.291	5[a]	2	-3	-20.88
4/18/00	64.76	2.171	5[a]	2	-3	-35.11
5/10/00	8.55	0.287	5[a]	2	-3	-4.64
5/16/00	5.81	0.195	5[a]	2	-3	-3.15
6/20/00	2.77	0.093	5[a]	2	-3	-1.50

a Reported as not detected; value shown is ½ sample quantitation limit.
b Acidity, total alkalinity, & net alkalinity are reported as mg/l $CaCO_3$ or lbs $CaCO_3$/day/mi^2.

Table E-10 Net Alkalinity Difference – Crab Orchard Ck. (COC-3) Relative to Target

Sample Event Date	COC-3 Flow	COC-3 Net Alkalinity Load	PDFE[a]	Target Net Alkalinity Load	Magnitude Of Difference
	[cfs/mi^2]	[lbs/day/mi^2][b]	[%]	[lbs/day/mi^2][b]	[lbs/day/mi^2][b]
10/5/99	—	—	—	—	—
10/13/99	0.079	-0.427	83.5	4.82	-5.25
10/26/99	0.009	-1.48	99.4	0.530	-2.01
11/8/99	0.046	-0.249	88.9	2.77	-3.02
11/15/99	0.017	-0.830	96.9	1.03	-1.86
12/1/99	0.038	-0.204	90.6	2.29	-2.50
12/15/99	1.072	0	46.2	64.7	-64.7
1/12/00	1.700	0	34.3	102.8	-102.8
2/16/00	—	—	—	—	—
3/9/00	1.291	-20.88	41.5	77.9	-98.8
4/18/00	2.171	-35.11	27.0	131.2	-166.3
5/10/00	0.287	-4.64	67.8	17.3	-21.9
5/16/00	0.195	-3.15	72.2	11.7	-14.8
6/20/00	0.093	-1.50	81.4	5.61	-7.11

a Percent of Days Flow Is Exceeded.
b Net alkalinity is reported as lbs $CaCO_3$/day/mi^2.

Table E-11 Smith Branch Calculated Net Alkalinity

Sample Date	Smith Branch Flow At SB-1		Acidity	Total Alkalinity	Net Alkalinity	
	[cfs]	[cfs/mi^2]	[mg/l][b]	[mg/l][b]	[mg/l][b]	[lbs/day/mi^2][b]
10/5/99	0.09	0.029	12	11	-1	-0.157
10/13/99	0.22	0.071	10	8	-2	-0.767
10/26/99	0.15	0.049	12	11	-1	-0.262
11/8/99	0.23	0.074	16	9	-7	-2.208
11/15/99	0.12	0.039	12	11	-1	-0.209
12/1/99	0.13	0.042	5[a]	7	2	0.453
12/15/99	2.13	0.689	5[a]	7	2	7.43
1/12/00	4.11	1.329	5[a]	4	-1	-7.17
2/16/00	13.51	4.369	5[a]	2	-3	-70.7
3/9/00	2.66	0.860	5[a]	4	-1	-4.64
4/18/00	4.34	1.404	5[a]	3	-2	-15.1
5/10/00	0.98	0.317	5[a]	5	0	0
5/16/00	0.53	0.171	5[a]	6	1	0.924
6/20/00	0.32	0.103	5[a]	7	2	1.12

a Reported as not detected; value shown is ½ sample quantitation limit.
b Acidity, total alkalinity, & net alkalinity are reported as mg/l $CaCO_3$ or lbs $CaCO_3$/day/mi^2.

Table E-12 Net Alkalinity Difference – Smith Branch Relative to Target

Sample Event Date	Smith Branch Flow	Smith Branch Net Alkalinity Load	PDFE[a]	Target Net Alkalinity Load	Magnitude Of Difference
	[cfs/mi^2]	[lbs/day/mi^2][b]	[%]	[lbs/day/mi^2][b]	[lbs/day/mi^2][b]
10/5/99	0.029	-0.157	92.8	1.74	-1.90
10/13/99	0.071	-0.767	84.8	4.35	-5.11
10/26/99	0.049	-0.262	88.5	2.92	-3.19
11/8/99	0.074	-2.208	84.1	4.58	-7.39
11/15/99	0.039	-0.209	90.3	2.37	-2.58
12/1/99	0.042	0.453	89.6	2.53	-2.08
12/15/99	0.689	7.43	55.9	41.6	-34.1
1/12/00	1.329	-7.17	41.0	79.8	-87.0
2/16/00	4.369	-70.7	11.9	263.2	-333.9
3/9/00	0.860	-4.64	51.8	51.9	-56.6
4/18/00	1.404	-15.1	39.7	84.6	-99.7
5/10/00	0.317	0	66.7	19.1	-19.1
5/16/00	0.171	0.924	73.8	10.3	-9.35
6/20/00	0.103	1.12	80.0	6.17	-5.05

a Percent of Days Flow Is Exceeded.
b Net alkalinity is reported as lbs $CaCO_3$/day/mi^2.

Table E-13 Crab Orchard Creek (COC-2) Calculated Net Alkalinity

Sample Date	Crab Orchard Creek Flow at COC-2		Acidity	Total Alkalinity	Net Alkalinity	
	[cfs]	[cfs/mi^2]	[mg/l][b]	[mg/l][b]	[mg/l][b]	[lbs/day/mi^2][b]
10/5/99	0.56	0.017	5[a]	6	1	0.090
10/13/99	2.33	0.069	10	2	-8	-3.00
10/26/99	0.6	0.018	5[a]	5	0	0
11/8/99	2.16	0.064	5[a]	3	-2	-0.695
11/15/99	1.23	0.037	5[a]	3	-2	-0.396
12/1/99	1.48	0.044	5[a]	2	-3	-0.714
12/15/99	34.12	1.018	5[a]	5	0	0
1/12/00	49.61	1.480	5[a]	4	-1	-7.98
2/16/00	146.83	4.379	5[a]	3	-2	-47.2
3/9/00	40.39	1.205	5[a]	3	-2	-13.0
4/18/00	69.29	2.067	5[a]	2	-3	-33.4
5/10/00	11.12	0.332	5[a]	2	-3	-5.37
5/16/00	4.56	0.136	5[a]	3	-2	-1.47
6/20/00	4.62	0.138	5[a]	3	-2	-1.49

a Reported as not detected; value shown is ½ sample quantitation limit.
b Acidity, total alkalinity, & net alkalinity are reported as mg/l $CaCO_3$ or lbs $CaCO_3$/day/mi^2.

Table E-14 Net Alkalinity Difference – Crab Orchard Ck. (COC-2) Relative to Target

Sample Event Date	COC-2 Flow	COC-2 Net Alkalinity Load	PDFE[a]	Target Net Alkalinity Load	Magnitude Of Difference
	[cfs/mi^2]	[lbs/day/mi^2][b]	[%]	[lbs/day/mi^2][b]	[lbs/day/mi^2][b]
10/5/99	0.017	0.090	96.9	1.03	-0.938
10/13/99	0.069	-3.00	85.1	4.19	-7.19
10/26/99	0.018	0	96.5	1.11	-1.11
11/8/99	0.064	-0.695	85.7	3.87	-4.57
11/15/99	0.037	-0.396	90.9	2.21	-2.61
12/1/99	0.044	-0.714	89.1	2.69	-3.40
12/15/99	1.018	0	47.5	61.4	-61.4
1/12/00	1.480	-7.98	38.3	89.3	-97.3
2/16/00	4.379	-47.2	11.8	264.8	-312.0
3/9/00	1.205	-13.0	42.8	72.7	-85.7
4/18/00	2.067	-33.4	28.5	124.9	-158.3
5/10/00	0.332	-5.37	66.2	20.0	-25.4
5/16/00	0.136	-1.47	76.3	8.22	-9.69
6/20/00	0.138	-1.49	76.2	8.30	-9.79

a Percent of Days Flow Is Exceeded.
b Net alkalinity is reported as lbs $CaCO_3$/day/mi^2.

Table E-15 Mill Creek Calculated Net Alkalinity

Sample Date	Mill Creek Flow At MC-1		Acidity	Total Alkalinity	Net Alkalinity	
	[cfs]	[cfs/mi^2]	[mg/l][b]	[mg/l][b]	[mg/l][b]	[lbs/day/mi^2][b]
10/5/99	0.27	0.033	5[a]	24	19	3.38
10/13/99	0.59	0.072	5[a]	17	12	4.67
10/26/99	0.24	0.029	5[a]	22	17	2.69
11/8/99	0.61	0.075	5[a]	16	11	4.43
11/15/99	0.03	0.004	5[a]	19	14	0.277
12/1/99	0.28	0.034	5[a]	11	6	1.11
12/15/99	7.91	0.968	5[a]	5	0	0
1/12/00	11.57	1.416	5[a]	4	-1	-7.63
2/16/00	37.87	4.634	5[a]	2	-3	-75.0
3/9/00	9.25	1.132	5[a]	3	-2	-12.2
4/18/00	13.28	1.625	5[a]	3	-2	-17.5
5/10/00	2.08	0.254	5[a]	6	1	1.37
5/16/00	1.07	0.131	5[a]	8	3	2.12
6/20/00	0.70	0.086	5[a]	12	7	3.23

a Reported as not detected; value shown is ½ sample quantitation limit.
b Acidity, total alkalinity, & net alkalinity are reported as mg/l $CaCO_3$ or lbs $CaCO_3$/day/mi^2.

Table E-16 Net Alkalinity Difference – Mill Creek Relative to Target

Sample Event Date	Mill Creek. Flow	Mill Creek. Net Alkalinity Load	PDFE[a]	Target Net Alkalinity Load	Magnitude Of Difference
	[cfs/mi^2]	[lbs/day/mi^2][b]	[%]	[lbs/day/mi^2][b]	[lbs/day/mi^2][b]
10/5/99	0.033	3.38	91.8	1.98	1.41
10/13/99	0.072	4.67	84.8	4.35	0.323
10/26/99	0.029	2.69	92.8	1.74	0.953
11/8/99	0.075	4.43	84.3	4.51	-0.079
11/15/99	0.004	0.277	100.0	0.348	-0.071
12/1/99	0.034	1.11	91.4	2.06	-0.947
12/15/99	0.968	0	49.0	58.5	-58.5
1/12/00	1.416	-7.63	39.5	85.4	-93.0
2/16/00	4.634	-75.0	10.8	279.8	-358.8
3/9/00	1.132	-12.2	44.6	68.5	-80.7
4/18/00	1.625	-17.5	35.4	98.0	-115.5
5/10/00	0.254	1.37	69.3	15.3	-14.0
5/16/00	0.131	2.12	76.7	7.90	-5.79
6/20/00	0.086	3.23	82.6	5.14	-1.91

a Percent of Days Flow Is Exceeded.
b Net alkalinity is reported as lbs $CaCO_3$/day/mi^2.

Table E-17 Crab Orchard Creek (COC-1) Calculated Net Alkalinity

Sample Date	Crab Orchard Creek Flow at COC-1		Acidity	Total Alkalinity	Net Alkalinity	
	[cfs]	[cfs/mi^2]	[mg/l][b]	[mg/l][b]	[mg/l][b]	[lbs/day/mi^2][b]
10/5/99	0.76	0.016	5[a]	12	7	0.607
10/13/99	3.81	0.081	5[a]	4	-1	-0.435
10/26/99	0.78	0.017	5[a]	6	1	0.089
11/8/99	3.01	0.064	5[a]	5	0	0
11/15/99	1.61	0.034	5[a]	7	2	0.368
12/1/99	1.46	0.031	5[a]	5	0	0
12/15/99	40.46	0.857	5[a]	5	0	0
1/12/00	60.45	1.280	5[a]	6	1	6.90
2/16/00	207.4	4.392	5[a]	3	-2	-47.4
3/9/00	49.44	1.047	5[a]	3	-2	-11.3
4/18/00	99.75	2.112	5[a]	3	-2	-22.8
5/10/00	15.63	0.331	5[a]	4	-1	-1.79
5/16/00	8.14	0.172	5[a]	5	0	0
6/20/00	6.17	0.131	5[a]	5	0	0

a Reported as not detected; value shown is ½ sample quantitation limit.
b Acidity, total alkalinity, & net alkalinity are reported as mg/l $CaCO_3$ or lbs $CaCO_3$/day/mi^2.

Table E-18 Net Alkalinity Difference – Crab Orchard Ck. (COC-1) Relative to Target

Sample Event Date	COC-1 Flow	COC-1 Net Alkalinity Load	PDFE[a]	Target Net Alkalinity Load	Magnitude Of Difference
	[cfs/mi^2]	[lbs/day/mi^2][b]	[%]	[lbs/day/mi^2][b]	[lbs/day/mi^2][b]
10/5/99	0.016	0.607	97.3	0.948	-0.341
10/13/99	0.081	-0.435	83.4	4.90	-5.34
10/26/99	0.017	0.089	96.9	1.03	-0.938
11/8/99	0.064	0	85.7	3.87	-3.87
11/15/99	0.034	0.368	91.4	2.06	-1.69
12/1/99	0.031	0	92.2	1.90	-1.90
12/15/99	0.857	0	51.9	51.7	-51.7
1/12/00	1.280	6.90	41.6	77.3	-70.4
2/16/00	4.392	-47.4	11.8	265.6	-312.9
3/9/00	1.047	-11.3	46.8	63.2	-74.5
4/18/00	2.112	-22.8	27.9	127.3	-150.0
5/10/00	0.331	-1.79	66.2	20.0	-21.8
5/16/00	0.172	0	73.6	10.4	-10.4
6/20/00	0.131	0	76.7	7.90	-7.90

a Percent of Days Flow Is Exceeded.
b Net alkalinity is reported as lbs $CaCO_3$/day/mi^2.

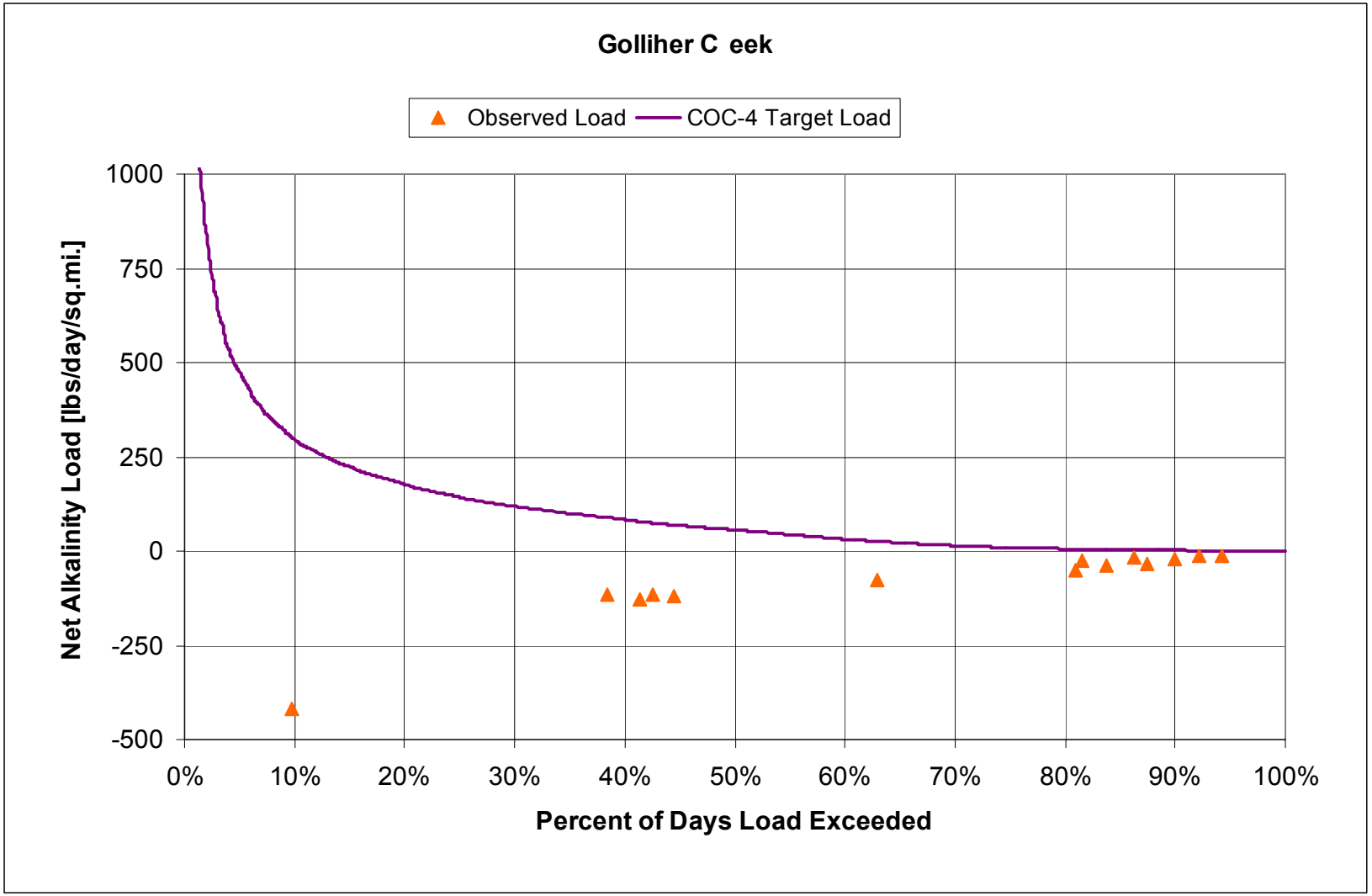

Figure E-1 Net Alkalinity Difference from Target – Golliher Creek

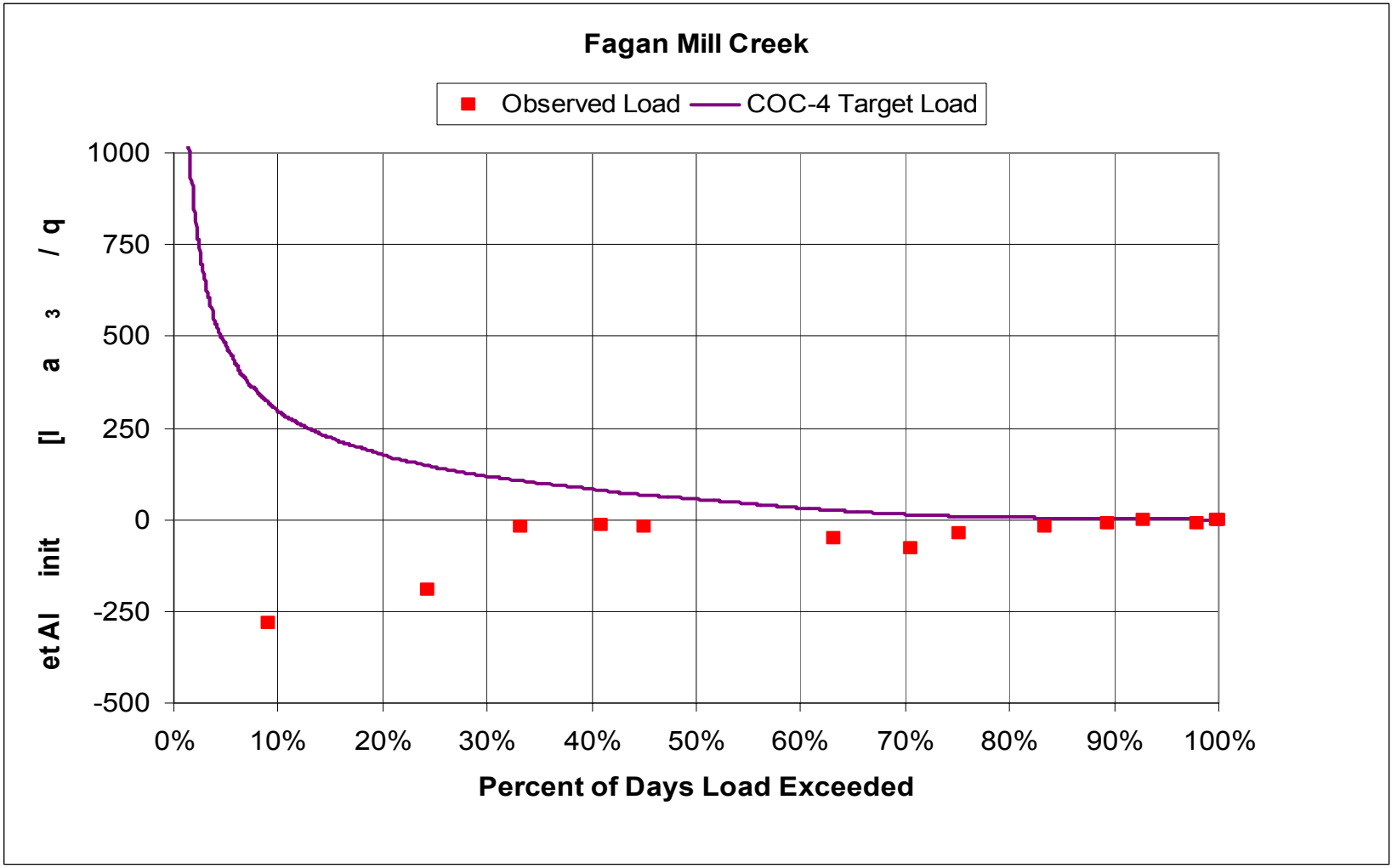

Figure E-2 Net Alkalinity Difference from Target – Fagan Mill Creek

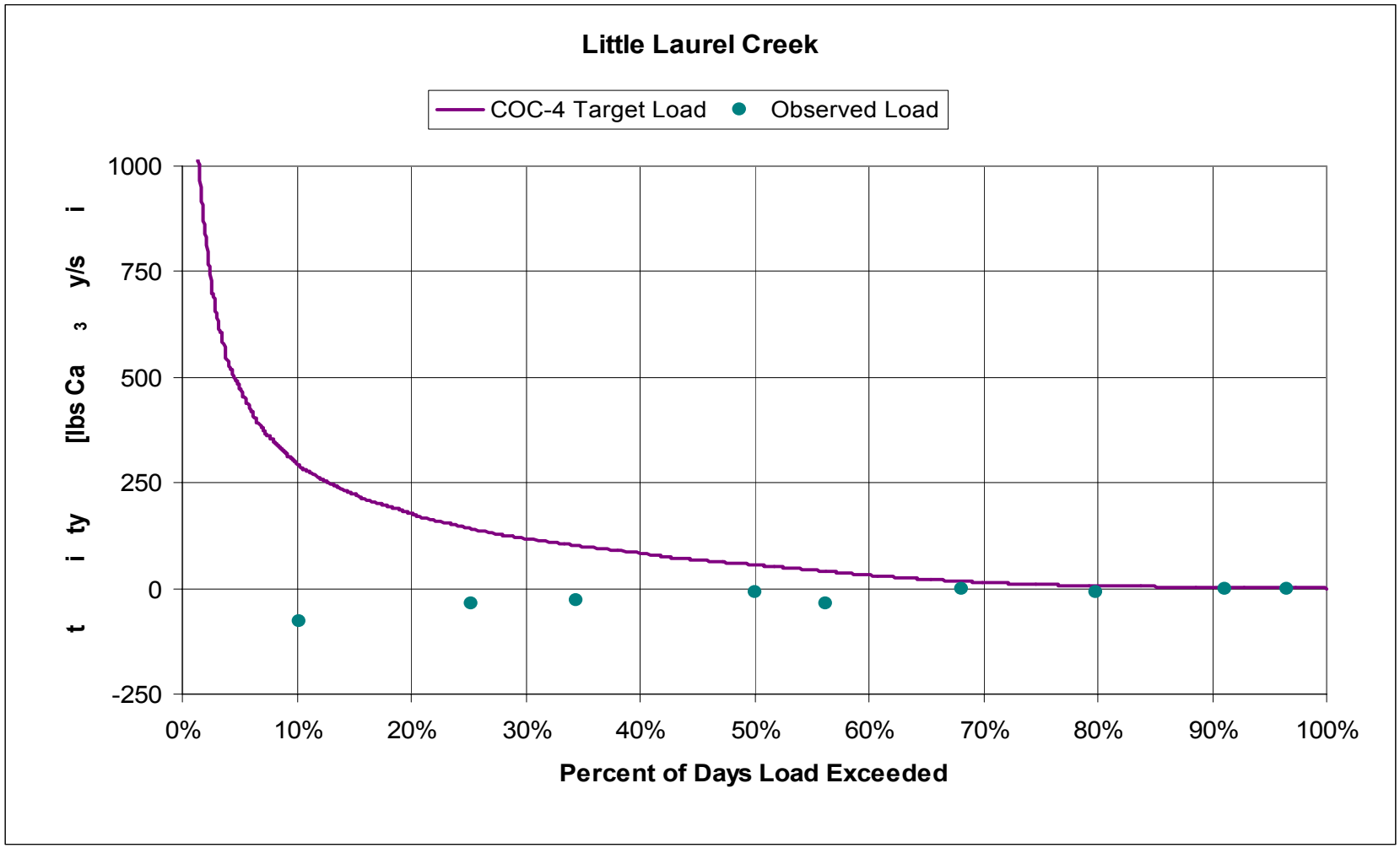

Figure E-3 Net Alkalinity Difference from Target – Little Laurel Creek

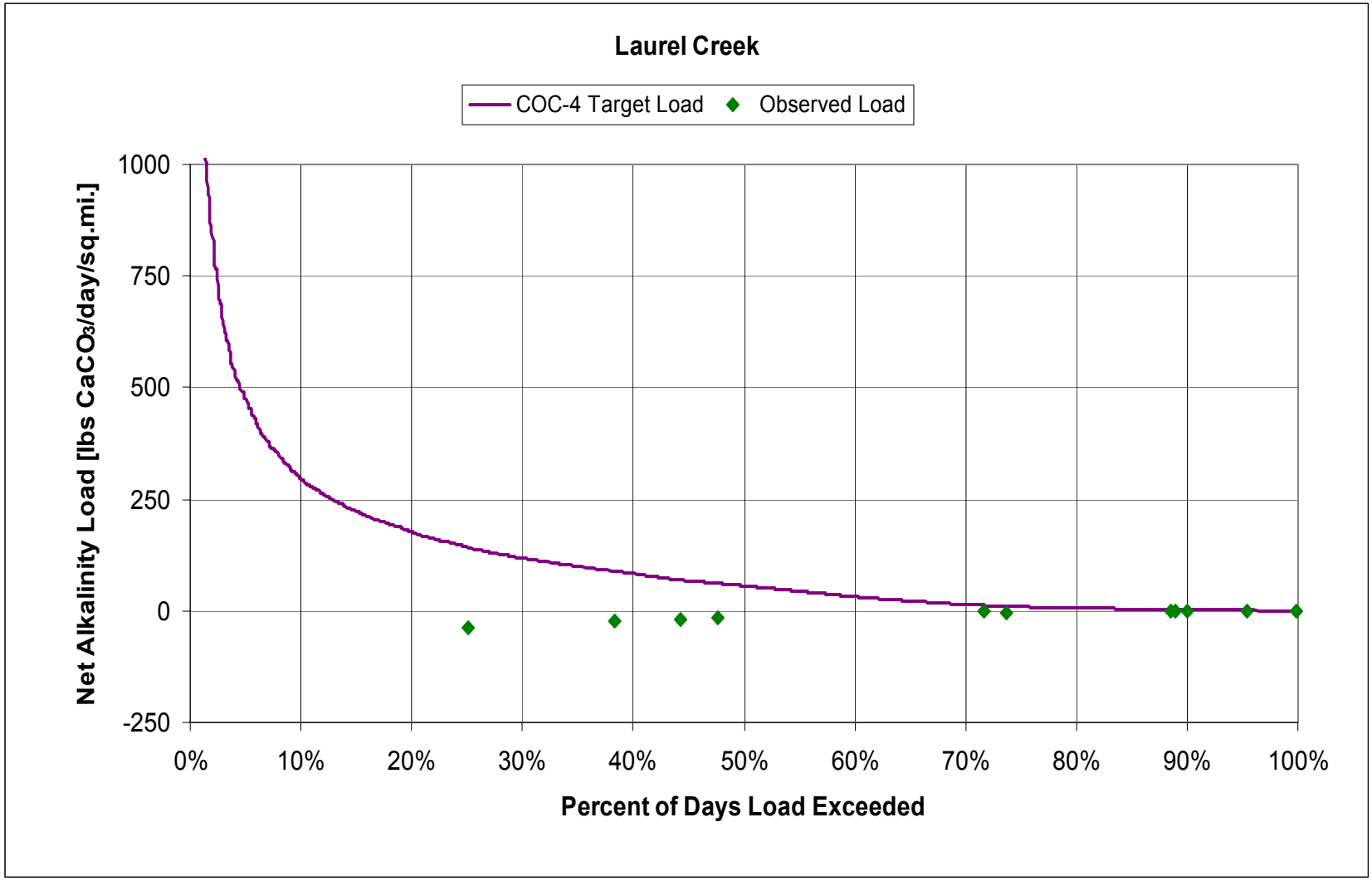

Figure E-4 Net Alkalinity Difference from Target – Laurel Creek

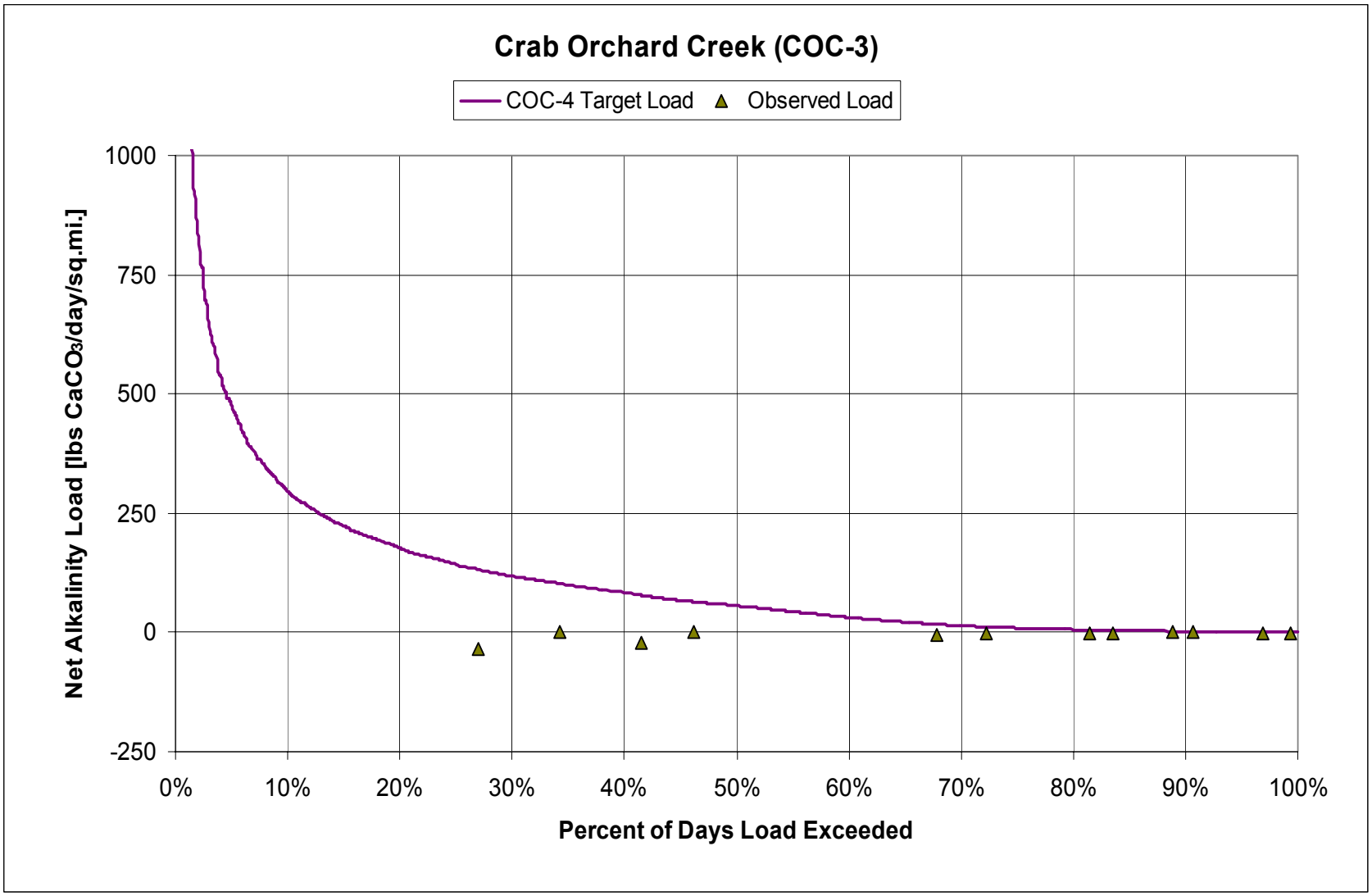

Figure E-5 Net Alkalinity Difference from Target – Crab Orchard Creek (COC-3)

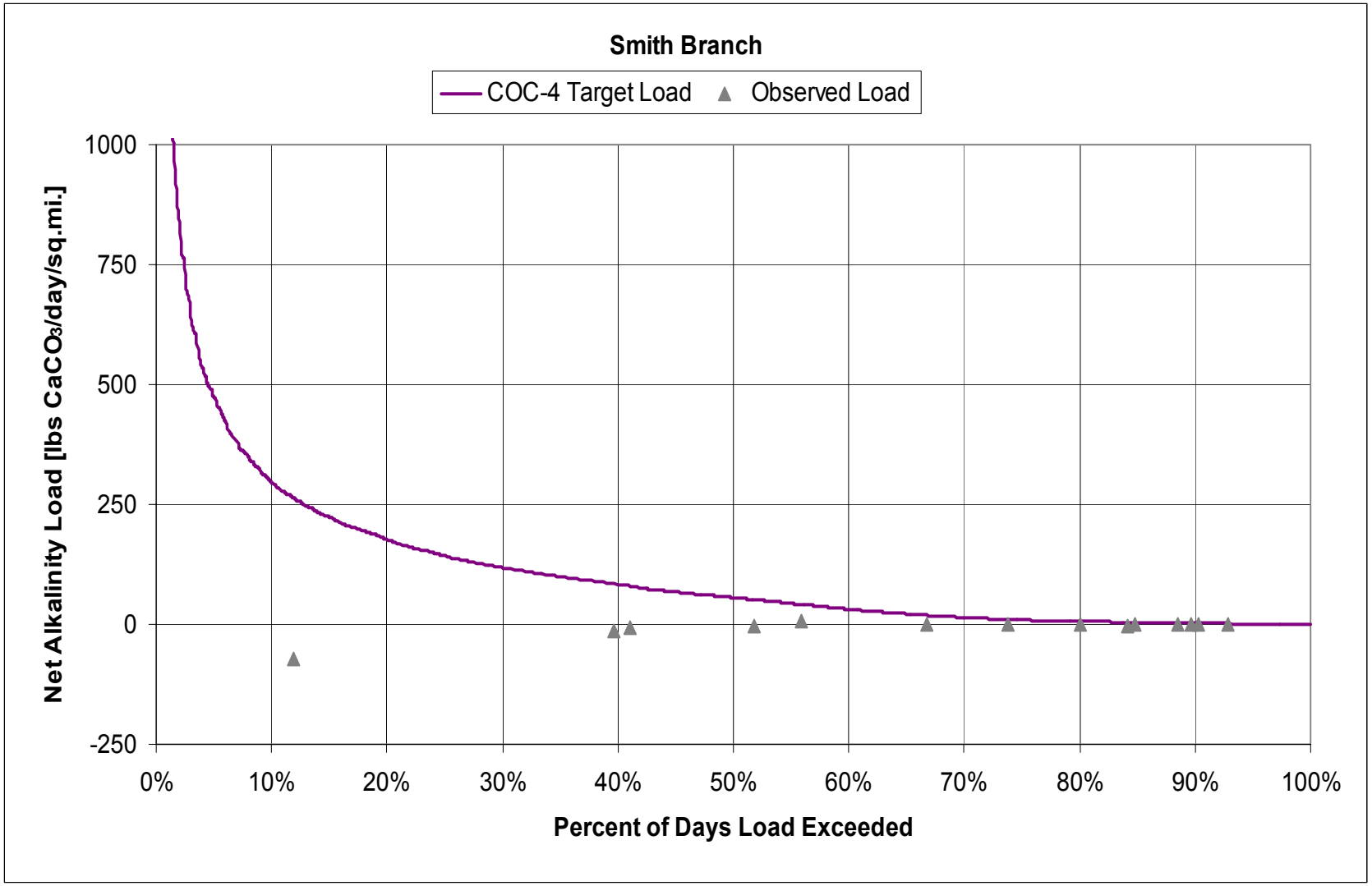

Figure E-6 Net Alkalinity Difference from Target – Smith Branch

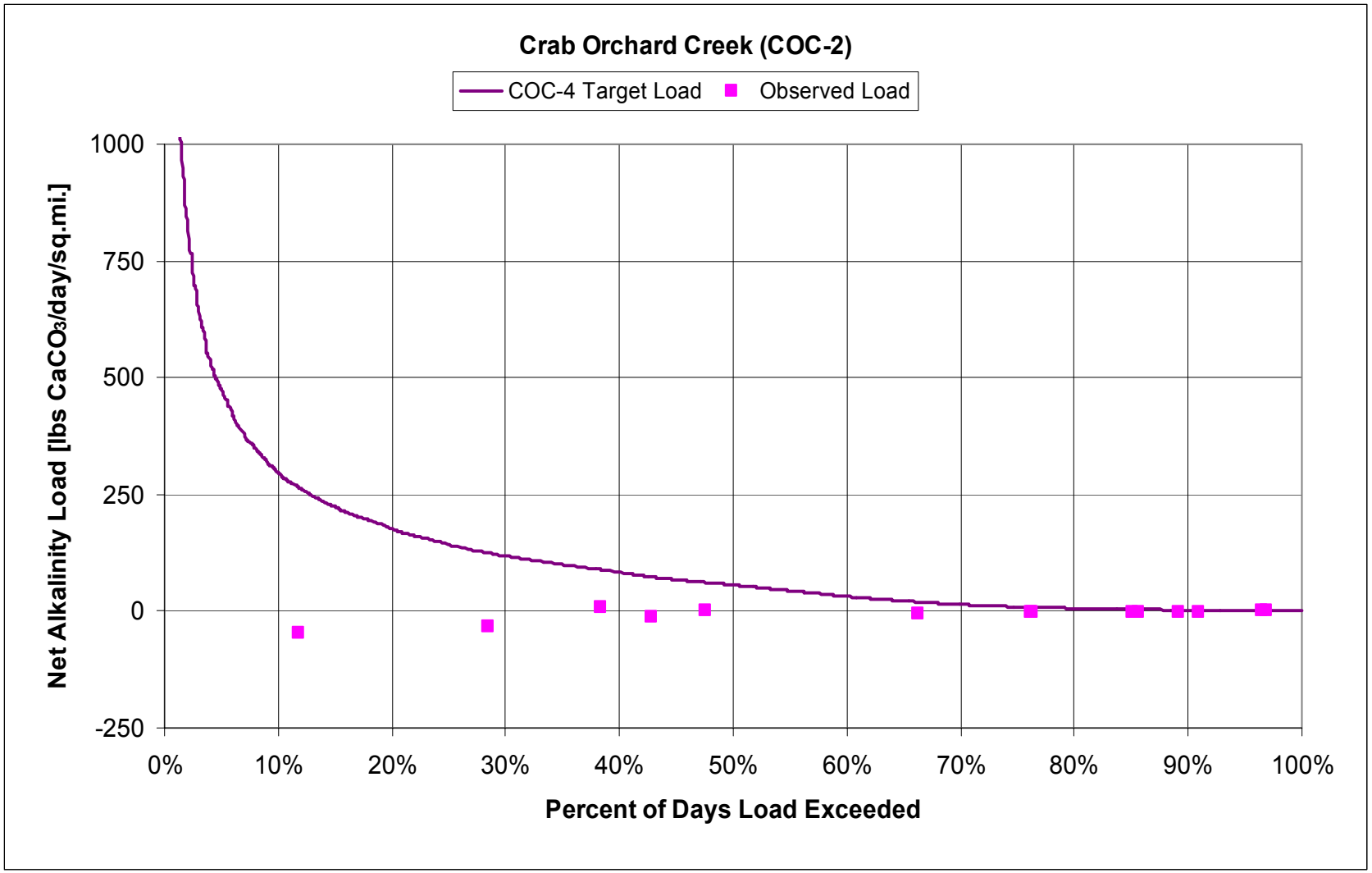

Figure E-7 Net Alkalinity Difference from Target – Crab Orchard Creek (COC-2)

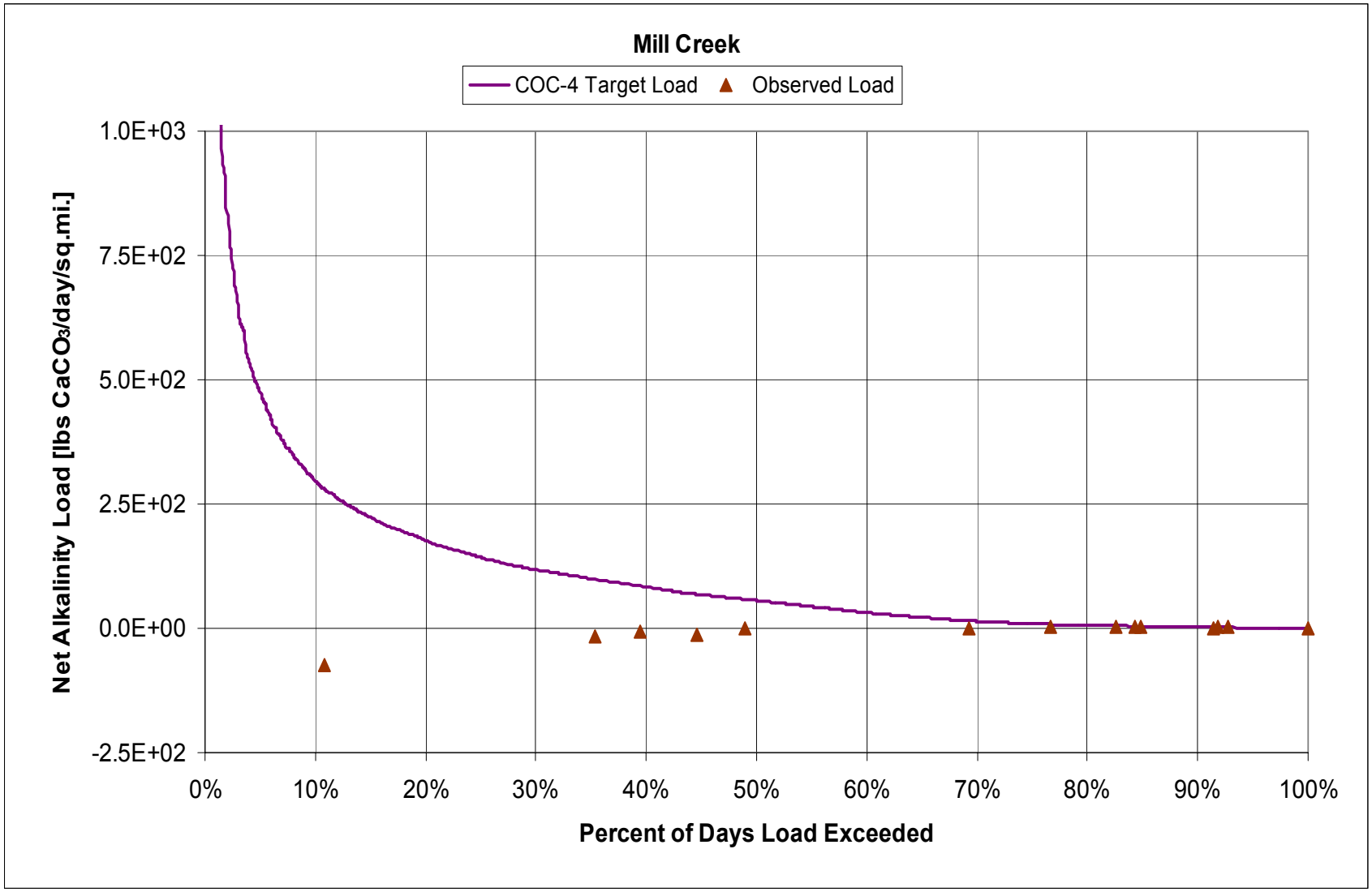

Figure E-8 Net Alkalinity Difference from Target – Mill Creek

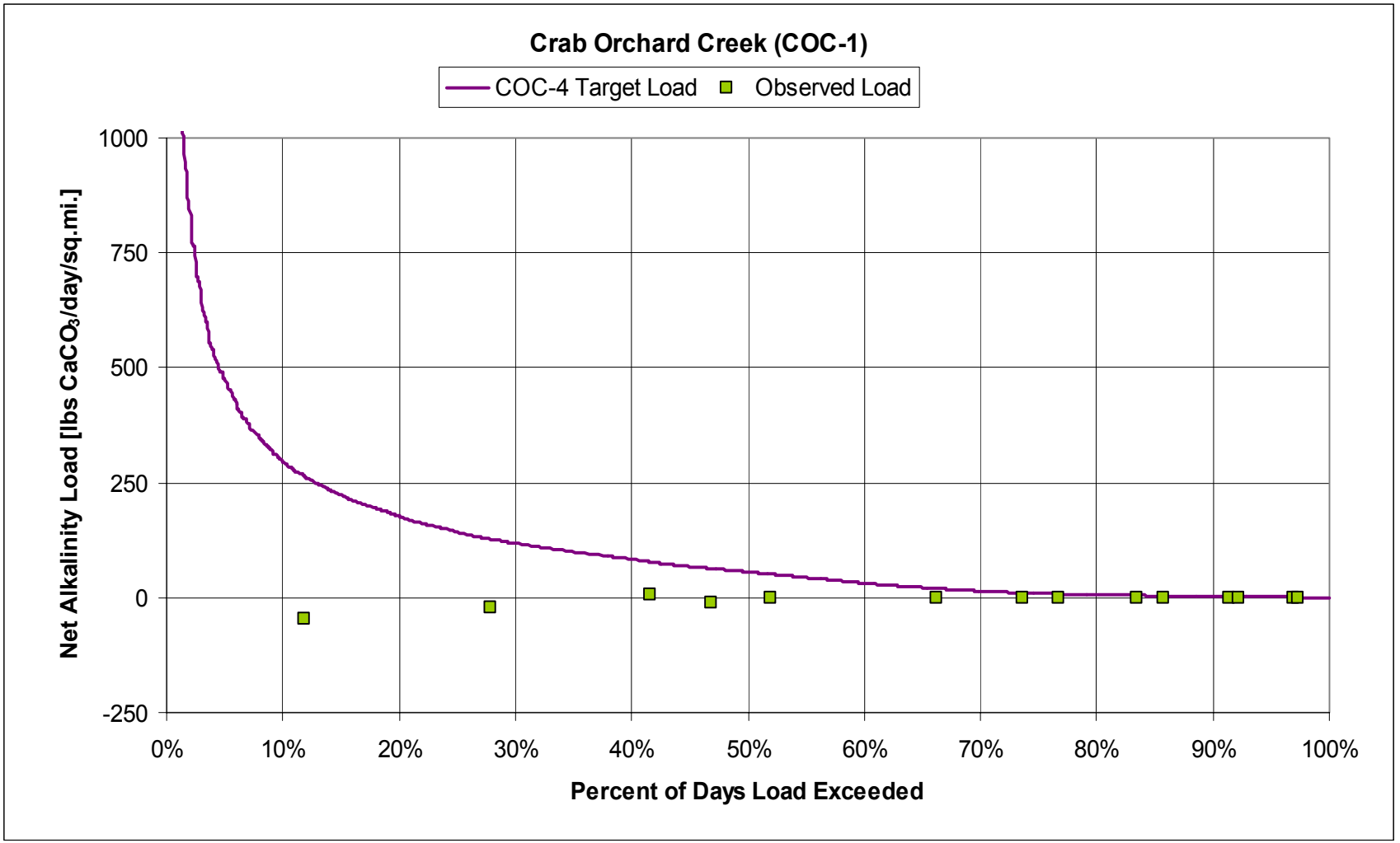

Figure E-9 Net Alkalinity Difference from Target – Crab Orchard Creek (COC-1)

APPENDIX F

Public Notice Announcement

STATE OF TENNESSEE
DEPARTMENT OF ENVIRONMENT AND CONSERVATION
DIVISION OF WATER POLLUTION CONTROL

PUBLIC NOTICE OF AVAILABILITY OF PROPOSED TOTAL MAXIMUM DAILY LOAD (TMDL) FOR pH IN CRAB ORCHARD CREEK EMORY RIVER WATERSHED (HUC 06010208), TENNESSEE

Announcement is hereby given of the availability of Tennessee's proposed Total Maximum Daily Load (TMDL) for pH in the Crab Orchard Creek subwatershed, part of the Emory River watershed, located in eastern Tennessee. Section 303(d) of the Clean Water Act requires states to develop TMDLs for waters on their impaired waters list. TMDLs must determine the allowable pollutant load that the water can assimilate, allocate that load among the various point and nonpoint sources, include a margin of safety, and address seasonality.

Crab Orchard Creek is listed on Tennessee's final 1998 303(d) list as not supporting designated use classifications due, in part, to low pH associated with abandoned mines. The TMDL utilizes net alkalinity (as $CaCO_3$) as a surrogate for pH, a load duration curve developed from USGS continuous record station flow data, Tennessee's general water quality criteria, in-stream water quality monitoring data, and an appropriate Margin of Safety (MOS) to establish loadings of net alkalinity (as $CaCO_3$) which will result in the attainment of water quality standards for pH.

The proposed pH TMDL may be downloaded from the Department of Environment and Conservation website:

http://www.state.tn.us/environment/wpc/tmdl.htm

Technical questions regarding this TMDL should be directed to the following members of the Division of Water Pollution Control staff:

Bruce R. Evans, P.E., Watershed Management Section
Telephone: 615-532-0668

Sherry H. Wang, Ph.D., Watershed Management Section
Telephone: 615-532-0656

Persons wishing to comment on the TMDLs are invited to submit their comments in writing no later than September 20, 2001 to:

Division of Water Pollution Control
Watershed Management Section
6th Floor, L & C Annex
401 Church Street
Nashville, TN 37243-1534

All comments received prior to that date will be considered when revising the TMDL for final submittal to the U.S. Environmental Protection Agency.

The TMDL and supporting information are on file at the Division of Water Pollution Control, 6th Floor, L & C Annex, 401 Church Street, Nashville, Tennessee. They may be inspected during normal office hours. Copies of the information on file are available on request.